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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G06F 3/00, 3/033, 3/023, G09B 21/00, A61F 4/00	A1	(11) International Publication Number: WO 96/30822 (43) International Publication Date: 3 October 1996 (03.10.96)

(21) International Application Number: PCT/US95/03591

(22) International Filing Date: 27 March 1995 (27.03.95)

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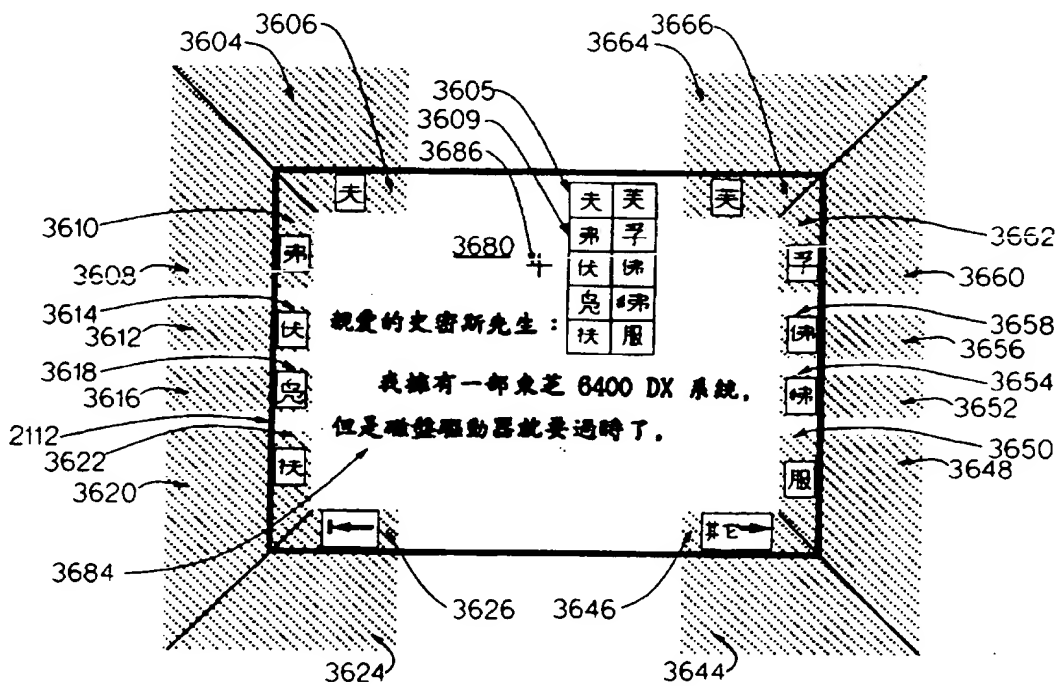
(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LU, LV, MD, MG, MN, MW, MX, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, MW, SD, SZ, UG), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD OF AND APPARATUS FOR DATA ENTRY

(57) Abstract



The apparatus and method of the invention relate to data entry in ideographic languages, including Chinese, Japanese and Korean, and to interactive displays and interactive display methods for use by persons temporarily or permanently lacking normal motor capabilities. In a preferred embodiment, each option of a menu is associated respectively with a selectable region (3606), (3610), etc.) displayed adjacent an edge of a display (2112), forming a perimeter menu and leaving a region (3680) in the center of the perimeter menu for the output of an application program. Selectable regions may be on the display, outside the display, or both. A menu option may be selected by clicking on the associated selectable region, by dwelling on it for a selection threshold period or by a cursor path toward the selectable region, or by a combination thereof. Remaining dwell time required to select a selectable region is preferably indicated by the brightness of the selectable region. Submenus of a perimeter menu may also be perimeter menus and the location of a submenu option may be foretold by the appearance of its parent menu option. Menu options may be ideographs sharing a sound, a structure or another characteristic. Ideographs, which may be homophones of one another, may be associated with colored indicating regions and selection of an ideograph may be made by speaking the name of the associated color.

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Method of and Apparatus for Data Entry

Technical Field

The present invention relates generally to interactive display terminals and interactive display methods, and more to interactive display terminals and interactive display methods for use by persons temporarily or permanently lacking normal motor capabilities. It also relates to systems and methods for the assessment of the motor capabilities of persons lacking normal motor capabilities. It further relates to interactive display terminals and interactive display methods for use in speech synthesis for persons having impaired speech. It also relates to systems and methods for the control of devices, including appliances, by persons lacking normal motor capabilities. It further relates to interactive display terminals and interactive display methods for selecting one menu option from a menu. It further relates to systems and methods utilizing sound recognition for selecting a menu option from a menu. It further relates to data and order entry systems including, and data and order entry methods utilizing, an interactive display terminal. It also relates to interactive display terminals and interactive display methods for displaying and selecting ideographic characters, such as are used in the Chinese, Japanese and Korean languages. It also relates to interactive display terminals and interactive display methods for producing an indication of progress toward and/or away from selection of a menu option.

Background Art

Many persons suffer from various neurogenic muscular disorders, such as Cerebral Palsy ("CP"), Traumatic Brain Injury, Spinal Cord Injury, Muscular Dystrophy, Amyotrophic Lateral Sclerosis and Multiple Sclerosis. These conditions can result in a reduced ability to voluntarily control or prevent the movement of parts of the body, including the head, limbs and digits, muscle stiffness, weakness, limited range of motion, abnormal posture, involuntary muscle tremors, involuntary muscle activity causing involuntary motion, impaired ability to voluntarily stop motion, impaired

ability to coordinate muscle activity, and/or impaired ability to sense the position of a part of th body. Any one of these symptoms may impair an affected individual's fine motor control. Moreover, while some individuals affected by a neuromuscular disorder may be able to exercise fine motor control with enormous effort, the struggle to do so often fatigues the individual, limiting the period of time the individual is capable or comfortable performing the fine motor control task.

Neuromuscular disorders are often systemic in effect, impairing an individual's ability to operate prosthetic devices, such as a wheelchair, and to perform the activities of daily life, such as speaking, walking and operating household appliances. Speech is frequently affected since the mechanics of producing speech require coordination of many muscle groups -- the muscles of the diaphragm which push air over the vocal cords, the muscles of the larynx, jaws, tongue and lips. The inability to use or coordinate these muscle groups may result in impaired speech. Depending upon the degree of impairment, speech may be totally absent, present but impaired to the point of unintelligibility, or intelligible on the whole but with occasional unintelligible words. The ability to walk is often affected since walking requires coordination and voluntary control of many muscle groups. Furthermore, impaired fine motor control may prevent or impede an individuals from effectively operating household appliances or computer input devices.

Devices are available which produce speech, control appliances and facilitate computer access for some persons having neuromuscular disorders ("NMD operators"). Devices which produce speech for individuals whose own speech is impaired, called Augmentative and Alternative Communication ("AAC") devices, allow the operator to select words or phrases by spelling the words, by specifying an abbreviation for the phrase or by selecting a sequence of symbols, and then speak the selected words or phrases using an electronic speech synthesizer. However, due to the systemic nature of neuromuscular disorders, NMD operators are often unable to efficiently use a standard keyboard and mouse. For example, an NMD operator who is unable to stop the movement of a limb with precision, when attempting to use a keyboard or mouse, may move his arm toward the target key or move the cursor toward the target object on the display but overshoot the target. If he has involuntary tremors and cannot hold a limb still, then, when attempting to use a keyboard, he may hit keys adjacent to his target key. If he has involuntary motion moving left to right, then, when attempting to use a keyboard, he may have difficulty accessing an intended key on the right side of the keyboard.

The benefits of interfacing an NMD operator to a general purpose computer so that he may contro

the computer and devices attached to it ("computer access") are both numerous, because many of the problems faced by the disabled are susceptible to a computer-driven solution, and profound, because of the psychological deprivation occasioned by a severe physical disability. The benefits potentially obtained through computer access for individuals affected by neuromuscular disorders include:

a. Speech synthesis. A computer connected to a speech synthesizer enables an NMD operator with impaired speech to direct the computer to speak for him.

b. Device control. A user who is physically unable to operate a household appliance, for example, a television, video cassette recorder, compact disc player, radio, alarm clock, telephone, light, thermostat, dimmer or power switch, may be able to control the appliance via a computer equipped with an interface he can control.

c. Access to general purpose computer applications. NMD operators may make use of the same general purpose computer application programs ("applications") as able-bodied users, including applications for word processing, database, computer-aided instruction, access to literature accessible via computer, spreadsheet, time management and computer utilities.

d. Enhanced self-esteem and peer approval. Adolescents with CP are obviously different from their peers. They are often surrounded by non-normative assistive technology, e.g. wheelchair or walker, special school bus equipped with a chair lift, stair lift, standing aid, AAC device, feeding apparatus, bath seat, toiletting apparatus, etc. In addition, they may drool, lacking the ability to coordinate lip closure with swallowing. Nonetheless they are adolescents and need peer approval to support them in their maturation from dependent children to independent adults. Today, demonstrated facility with a computer is an emblem of intelligence among adolescents, so computer use provides adolescents the opportunity to prove their intelligence and thus potentially rewards NMD operators with both self-esteem and peer approval.

e. Privacy. Some severely disabled school-aged children require nearly constant physical assistance to transfer them to and from bed, to feed them, help them with toiletting and personal hygiene, etc. Because they are constantly attended, all their mistakes in class or when doing homework are known to their attendant, often a family member. They do not have the opportunity to make mistakes in private. Computer use, if it can be done without assistance, affords the NMD operator the opportunity to avoid the embarrassment of showing their failings to their attendant.

f. Expanded personal interaction. Some severely disabled individuals, e.g. quadriplegics, are essentially incarcerated by their disability. They interact with their family or their caretakers,

depending upon whether they live at home or in an institution. Their circle of friends is oft very small. Using a computer and a modem, they can expand their circle of friends to include the tens of thousands of people who periodically connect to worldwide electronic networks to trade information on topics of mutual interest. Moreover, the interaction via present computer networks is mostly textual; there is no voice or visual interaction between users. Since messages are customarily composed and read off-line to minimize connect time charges, no one even knows how long it took the sender to enter the text. Electronic networks thus afford the disabled user an opportunity to relate to others on an equal footing, not as a disabled person to his able-bodied peers, something many NMD operators dearly want to do but were never able to.

NMD operators vary widely in their motor capabilities. Even individuals having the same medical diagnosis may require completely different technologies for computer access. Many NMD operators are able to use an oversize keyboard, a devices having a pressure-sensitive surface divided into squares, each square associated with a letter of the alphabet. The squares may be sized to match the operator's abilities, but typically each square is two inches on either side. NMD operators who are unable to efficiently use an oversize keyboard may use another conventional computer access solution, called an "on-screen keyboard", which, as illustrated in Figure 1, is a picture of keyboard drawn on a computer display (1101). The operator selects a letter by pointing to that letter's key image on the display with a pointing device ("pointer"), then indicating that he has reached his target either by operating a switch, a process called selection by click, or by maintaining the location indicated by the pointer ("dwelling") on the key image for a predetermined period of time (the "selection threshold"), a process called selection by dwell. Switch operation includes, but is not limited to, each of the following: opening the switch, closing the switch, opening the switch multiple times within a predetermined period, and closing the switch multiple times within a predetermined period. A program executing on the computer determines which letter the operator has selected and processes the letter or passes it to some other application program which processes the letter as if it came from a true keyboard.

Conventional pointing devices include a mouse, trackball, joystick (which may be integrated into a keyboard, e.g. TrackPoint II®), stylus and graphics tablet, lightpen, thumb wheel, touch screen, touch panel, head pointer, occulometer, intraoral pointer and eye tracker. They may be active, e.g. a lightpen that emits an infrared beam, or passive, e.g. an eye tracker that uses images of an individual's eyes to determine where his eyes are focusing. Conventional switches include a button

on the mouse, a switch in the tip of the stylus actuated by pressure or the release of pressure, a switch mounted on the user's wheelchair operated by a turn of the head to or the switch below a keyboard key.

Dwell time may be continuous or discontinuous depending upon the operator's motor capabilities. In continuous dwelling, if the operator moves the cursor from one key image to another region of the display, the time accumulated on the key image is discarded so that if the operator returns to that key image he must dwell on it for the full selection threshold to select it. Discontinuous dwelling, by contrast, compensates for involuntary tremors which pull the operator off the desired key image. Accumulated dwell time on a key image is remembered, so that on return to a key image, the operator need only dwell for a period equal to the difference between the selection threshold and the previously accumulated dwell time for that key image. Accumulated dwell time is reset to zero for all key images following the selection of any one key image. Conventional on-screen keyboards do not indicate to the operator the dwell time associated with any key image.

There may be a single selection threshold period for all key images or each key image may be associated with its own selection threshold period. In the latter case, keys associated with shorter selection threshold periods are easier to select than keys associated with longer selection threshold periods.

As was mentioned earlier, computer access permits an NMD operator to run a variety of applications. One such application is speech synthesis. In a computer-based speech synthesis system, a computer system displaying an on-screen keyboard is connected to a speech synthesizer.. The operator spells the desired word or words using the on-screen keyboard. These are then spoken by the speech synthesizer. Another application of the on-screen keyboard is word processing. Figure 2 illustrates an example of a combined display of an on-screen keyboard and a word processing application program. The on-screen keyboard (0201) is shown on the lower portion of a display connected to a computer system (not shown) which also executes the word processing application program whose output (0203) appears on the upper portion of the display. Letters selected by the operator are input to the word processing application program.

Due to impaired fine motor control, many NMD operators have difficulty selecting a key image by click or by dwell and this difficulty increases as the size of the key image decreases. Figure 1 shows an on-screen keyboard containing 81 total keys including 26 alphabetic keys, 10 numeric

keys, 12 function keys, 4 arrow keys and 29 special purpose keys. Drawing this many key images on a display restricts the size of each key image making each very difficult for many NMD operators to select.

When a display is shared between application program output (0203) and an on-screen keyboard (0201), as is the display shown in Figure 2, the size of each key image must be reduced from its size in Figure 1 to allow space for the application program output. Thus, as more display space is allotted to application program output, the key images become more difficult for an NMD operator to select.

Many NMD operators have difficulty using the conventional dwell selectable on-screen keyboard because they cannot maintain a steady pointer position. The body member with which they control the pointer may move slightly ("drift") when they want it to remain still. One approach to this problem is a variation of the on-screen keyboard, depicted in Figures 3, 4 and 5 and called a quaternary on-screen keyboard ("quaternary keyboard"). The quaternary keyboard provides for larger key images. The alphabet is divided into four groups of letters, each displayed in one of the four quadrants (1302), (1304), (1306) and (1308) of the display, as shown in Figure 3. The operator selects one of the four groups by, for example, pointing to and dwelling on one quadrant of the display. The selected group is then exploded into four subgroups, each displayed in one quadrant of the display, as shown in Figure 4. Once more the operator selects one of the four. The selected group is exploded into four letters and each letter displayed in one quadrant of the display, as shown in Figure 5. The operator again selects one of the four. This letter is then input to an application program (not shown).

The quaternary keyboard illustrates the use of a menu hierarchy in computer access. Each of the four groups of letters (1302), (1304), (1306) and (1308) is a menu option. Each of these menu options is itself a menu which includes other menu options. A menu hierarchy exists if at least one of a menu's menu options is itself a menu. Hereinafter, a menu accessed from another menu may be called a submenu, and the options of the submenu may be called submenu options. If a menu hierarchy is narrow and deep, many selections are required to make the desired choice. If a menu hierarchy is broad and shallow, each layer is composed of many menu options.

The quaternary keyboard greatly expands the size of a single key image and thus accommodates certain NMD operators with drift or involuntary tremors. The cost of this adjustment is high

Instead of selecting a letter with one pointing motion and dwelling for one selection threshold, the quaternary keyboard requires three pointing motions and dwelling for three selection thresholds. Thus the operator's productivity is dramatically reduced from the standard on-screen keyboard depicted in Figure 1.

The computer access advantage gained from the quaternary keyboard is greatest when the quaternary keyboard occupies the entire display. In this configuration the size of each of the four active display regions is maximized, making them easier to hit and dwell on for the operator. However, this configuration allows no room on the display for the output of the application program being run by the operator, the reason he is sitting at the computer in the first place. This does not prevent the on-screen keyboard from passing letters to the application program since an application program need not be visible to be active, but it does prevent the operator from seeing what the application program has to show him. The more of the application program output that is displayed, the smaller the on-screen keyboard, the smaller each active region of the on-screen keyboard and the more difficult access becomes. Figure 6 illustrates a display combining a quaternary keyboard and output from two application programs.

Another conventional structure for selecting of a menu option from a menu is a pie menu A pie menu is an opaque region on a display divided into selectable slices, each slice associated with a menu option. The pie menu suffers some of the drawbacks discussed above, particularly that, while displayed the pie menu occupies more space than a linear menu and obscures much of the output of the operator's application program. For illustrations and a discussion of pie menus, see Callahan, Jack et. al., "An Empirical Comparison of Pie vs. Linear Menus", Computer Science Technical Report Series, TR-1919, University of Maryland, September 1987.

NMD operators who cannot effectively use a conventional keyboard or a pointing device may use a computer access method called "joystick patterns". Figure 7 depicts a conventional joystick pattern device. The device (1602) is connected to a joystick and to a computer. The operator pushes the joystick to the top, bottom, left, right, top left corner, top right corner, lower left corner or lower right corner, closing one of eight switch contacts within the joystick housing. That switch position is then indicated on the display (1604). A sequence of consecutive of switch closures encodes a letter or other programmed output that the device (1602) displays on an LCD display (1606) and sends to the connected computer, simulating keyboard input.

The conventional joystick pattern device is ill-suited for many NMD operators. The involuntary tremors common some neuromuscular disorders may result in unintended switch closures. In addition, the device does not provide an indication that the operator is moving a body member in an unintended direction until switch closure occurs. For example, an operator with CP who intends to move the joystick the right but actually moves it to the upper right receives no indication from the device, prior to switch closure, that he's not on target. Moreover, the device requires that the operator memorize the encoding of each letter or other output since there's no indication on the display (1606) which sequence encodes which letter. Further, the device provides no support for head pointing, although the head is often the best controlled part of an NMD operator's body.

NMD operators who cannot effectively use either a conventional keyboard or a pointing device but can reliably actuate a switch may use a computer access method called "scanning", which is subdivided by cursor control technique into three types of scanning: automatic, directed and step. In automatic scanning all the operators' options, for example, the letters of the alphabet, appear on either a static or dynamic display (depending upon the implementation), organized in rows and columns. At the scanning interval, usually about one second, a cursor moves from one row to the next. When the cursor indicates the row containing the letter the operator wants, he closes a switch. The machine now moves the cursor from one letter to the next within the selected row until the operator closes the switch again. The operator has now selected one letter. In directed scanning, like automatic scanning, the cursor moves at the frequency determined by the scanning interval, however, it moves only when the switch is closed. To select an option, such as a row or a letter in a row, the operator opens the switch while the cursor indicates the desired option. In step scanning, the cursor moves with each switch activation.

As one can well imagine, writing a sentence via any of these scanning techniques is an extremely slow process, since selecting a single letter may take many seconds.

Problems of computer access cascade and affect the quality of verbal interactions between AAC device operators ("AAC operators") and others. People speak much faster than they type. Not surprisingly, operators who speak with AAC devices, particularly NMD operators whose motor deficits impair their ability to use a keyboard, lag substantially in their conversations. The slow pace of an AAC operator's word production disrupts normal verbal interaction. Speaking persons, accustomed or not to the AAC operator's slow rate, often lose patience in conversations with AAC operators. They may prematurely terminate the conversation, read the AAC device display in an

attempt to guess at the AAC operator's intended utterance and so accelerate the interaction, lead the AAC operator, ask predominantly yes/no questions, change the topic of conversation with little input from the AAC operator and otherwise dominate the interaction. The AAC operator often has difficulty participating as an equal partner in the conversation. He may be unable to change the topic, interject a humorous comment in a timely fashion or respond to a question before the speaking person changes the topic. Slow AAC operators may be perceived as mentally slow. Thus the quality of verbal interactions where one party uses an AAC device to speak depends significantly upon the AAC operator's rate of word production.

Increasing an operator's letter or menu option selection rate proportionately increases his word production rate and increases the operator's productivity in data entry generally. Letter or menu option selection time includes the time the operator requires (a) to comprehend the menu options displayed, (b) to move the pointer to the desired menu option on the display, and, in selection by dwell, (c) the selection threshold period, or, in selection by click, (c) the time required to operate the switch. Decreasing any one of these increases the operator's productivity, assuming all other steps in the selection process are unaffected.

Personal interactions are composed of more than speech alone. People in conversation gesture to one another, use facial expressions, change the object of their gaze and make non-speech utterances (e.g. "hmmm-mmmm") to bid for a turn to speak, to grant such a bid made by the other party, to request to continue speaking and to acknowledge, accept or dispute what has been said. Ideally, the production of speech from an AAC devices does not distract the AAC operator from the personal interaction and subject matter of the conversation. This is possible if the operator habituates the AAC device access technique and menu structure, producing speech without focusing on each step of the process, much as automobile drivers habituate mechanical tasks, such as changing gears and switching between foot pedals, and focus their attention on pedestrians or traffic lights while operating their vehicle.

Another consequence of personal interaction during conversation for an AAC device operator is that the operator needs a way to easily enable and disable the AAC device operator interface so that movement the operator makes during personal interaction, for example, nodding his head, is not interpreted by the AAC device.

As noted previously, neurogenic muscular disorders may impair the ability of an individual to

sense the position of a body member. An NMD operator thus relies more than his able-bodied peer on the location of a cursor or similar automated indication of body member position. Conventional access methods which use a pointer do not provide additional feedback to the operator of the position of a body member.

Access methods which require the NMD operator to make the same movement for most selections, such as single switch access, mouth sticking (the use of a small rod held in the mouth and used to depress keys on a keyboard) and head sticking (the use of a rod mounted on the head and used to depress keys on a keyboard), may result in repetitive motion injury, particularly after years of use.

There are several aspects of the invention, each addressing one or more of the problems described above and/or one or more problems specifically addressed by that aspect of the invention. The objects, disclosure and description of each aspect is separately described below under one of the headings: (A) Perimeter Menu, (B) Confinement, (C) Dwell, (D) Path Directness, (E) Intersection, (F) Alignment, (G) Length Order, (H) Location Indication, (I) Sound Match, and (J) Ideographic Languages,. Where there is background art applicable to an aspect in addition to that described above, the additional background art is described below.

A & B. Perimeter Menu and Confinement

One object of the invention is to facilitate computer access by a disabled operator.

A further object of the invention is to facilitate menu selection by an operator having impaired ability to maintain a body member in a steady position.

Another object of the invention is to facilitate menu selection by an operator having impaired ability to stop motion.

Yet another object of the invention is to simultaneously display an application program window and a computer access menu which does not obstruct the application program window.

Another object of the invention is to allow an operator to enable and disable a menu.

A still further object of the invention is to synthesize speech for an operator having impaired

speech and impaired fine motor control.

Still another object of the invention is to facilitate device control for a disabled operator.

Another object of the invention is to reduce the cognitive demand of speech synthesis for the disabled.

A still further object of the invention is to enlarge the effective area of a selectable region without concomitantly reducing the area available for information display.

Another object of the invention is to speed data entry.

Yet another object of the invention is to facilitate computer access for an operator having impaired ability to sense the position of a body member used for computer access.

C. Dwell

Conventional systems allowing selection by dwell do not provide an indication to the operator of either how much dwell time has been accumulated for any selectable region or how much more dwell time is required to select a selectable region. Consequently, an operator of a conventional system who is dwelling on a intended selectable region has no indication, other than his estimation from prior use of the system, that he has nearly made his selection and can plan his next movement to the next selectable region or that he has very nearly made his selection and can begin moving to the next selectable region. Furthermore, an operator of a conventional system who is dwelling on an unintended selectable region, has no indication, other than his estimation from prior use of the system, of how close he is to making an unintended selection and thus how important it is to act quickly. Conventional systems using discontinuous dwell give no indication of the accumulated dwell time associated with a selectable region either when the operator dwells on that region or when the operator ceases dwelling on that region. Some disabled users can dwell relatively easily on their intended targets for short periods of time, but have difficulty dwelling for long periods. If such an operator knows that only a little more dwell time is needed he may be able to satisfy the dwell time required for selection, without preparing himself to dwell for an extended period.

Conventional menu-driven data entry and order entry systems incorporating pointing at intended

selections employ a two step selection procedure. In the first step the operator indicates, with a pointer, his intended selection. The system then provides feedback, for example, by highlighting the indicated selection, showing which selection the operator has indicated. In the second step, the operator selects the indicated selection, for example, by operating a switch. Thus, conventional data entry and order entry systems are ill-suited to circumstances where the operator cannot easily operate a switch while maintaining the pointer on the intended selection.

While the two step procedure is not complicated, many operators require some training to learn it, and, if they are infrequent users of the system, these operators may require refresher training. Simplifying the procedure further would lessen the need for initial and refresher training.

One object of the invention is to facilitate the use of systems allowing selection by dwell.

Still another object of the invention is to facilitate device control by the disabled.

A further object of the invention is to increase the independence of the disabled.

Yet another object of the invention is to facilitate the use of a data entry or order entry system by an intermittent operator.

Another object of the invention is to facilitate ordering by someone seated in a vehicle.

D. Path Directness

The on-screen keyboard with dwell selectable key images is ill-suited for use by many NMD operators. Selection by dwell may fatigue NMD operators or may require greater fine motor control than they bring to this task. Operators with impaired ability to stop motion and those having involuntary tremors have difficulty maintaining the location indicated by a pointer on a key image for a period sufficient to distinguish intentional dwelling from unintentional dwelling. Consequently, some NMD operators who try to use on-screen keyboards often miss their target key images and/or accidentally select unintended key images. Following such an error, the operator must erase his erroneous selection by selecting the backspace or undo key. As the number of erroneous selections increases, the operator's productivity decreases markedly, since each error requires a correction in which there might be another error.

Conventional on-screen keyboards require the ability to select by dwell or by click and thus are limited to operators with these capabilities. Conventional on-screen keyboards do not utilize the relatively intact motor capabilities of some NMD operators to compensate for impaired ability to select by dwell or by click or to speed up the slow process of selecting by dwell. For example, while an NMD operator may overshoot a key image, his directional control may be relatively intact. Conventional on-screen keyboards do not exploit this capability.

The dominant computer operating system for graphic applications on general purpose computer systems today is the Windows® Operating System. Windows® assigns meaning to the cursor location. When the operator moves the cursor on top of a menu item and clicks, Windows® interprets the action as manifesting an intent to choose that menu item. The operator's path to that menu item, whether direct or circuitous, is irrelevant. Operators who can move toward a target accurately but cannot maintain the location indicated by a pointer on the target cannot effectively use standard Windows® applications through the conventional interface to these applications.

Often NMD operators cannot steady a pointer while operating a switch; the act of operating the switch triggers involuntary muscle activity pulling the cursor off target. For these operators, conventional selection by click is not practicable. Conventional selection by dwell also requires greater fine motor control than many NMD operators bring to this task. Operators with impaired ability to stop motion may overshoot their intended target. Operators whose voluntary muscle activity is accompanied by some involuntary muscle activity affecting their directional control cannot point accurately. Operators with involuntary tremors cannot maintain the location indicated by a pointer on a key image. Consequently, NMD operators who try to use on-screen keyboards often miss their target key images and accidentally select unintended key images. Following such an error, the operator must erase his erroneous selection by selecting the backspace or undo key. As the number of erroneous selections increases, the operator's productivity decreases markedly, since each error requires a correction in which there might be another error.

Measures of an individual's fine motor control assist a physician or therapist in evaluating the effectiveness of a treatment program, including assistive technology, and in gauging the severity of a disability. Such measures help the physician or therapist in determining what treatment course to pursue and whether the severity of a certain disability justifies the risk of a particular treatment option, such as neurosurgery.

One object of the invention is to facilitate selection of an option from a menu.

Another object of the invention is to indicate to an operator moving a cursor toward an option in a menu displayed by a computer system, which option the computer system believes the operator is moving toward.

Another object of the invention is to display a menu on a display so that a large contiguous area on the display is not obstructed by the menu.

Still another object of the invention is to make use, in computer access, of relatively unimpaired directional control in persons having impaired fine motor control.

A further object of the invention is to indicate to an operator moving a cursor toward a dwell-selectable option in a menu, a changed selection threshold of the dwell-selectable option.

Yet another object of the invention is to more efficiently select an option from a menu on a display.

Another object of the invention is to speed up selection of an option from a menu by an operator having impaired ability to operate a switch while the operator simultaneously keeps a cursor location within a region on a display.

Another object of the invention is to help an operator with a disability control a pointer.

Yet another object of the invention is to speed data entry by an individual with a disability.

A still further object of the invention is to facilitate artificial speech generation by a person having impaired speech due to a neurogenic muscular disorder.

Yet another object of the invention is to facilitate device control by a person having a neurogenic muscular disorder.

Another object of the invention is to measure an individual's ability to move one of the individual's body members in a direct path from a starting position to an ending position.

Yet another object of the invention is to facilitate computer access for an individual who cannot stop movement cleanly.

E. Intersection

One object of the invention is to facilitate computer access by an operator having impaired ability to maintain a body member in a steady position.

Another object of the invention is to facilitate the selection of a desired menu option by an operator having impaired fine motor control.

A further object of the invention is to synthesize speech for an operator having impaired speech and impaired motor control.

Yet another object of the invention is to use an operator's directional control in computer access.

A still further object of the invention is, in selecting a menu option from a menu of dwell-selectable menu options, to compensate for an operator's impaired ability to maintain a body member in a steady position by using the operator's relatively intact motor capability .

F. Alignment

Conventional on-screen keyboards do not compensate for NMD operators' inability to stop motion. Suppose the operator has been fitted with a head pointing device so that his head motion moves the cursor and that he's using the quaternary keyboard shown in Figures 3, 4 and 5. Assume further that, as he attempts to point to the quadrant containing the "j" key image (1308) in Figure 3, he is unable to stop on that quadrant and continues turning 20 more degrees to the left. There are two known ways of responding to this situation: (1) the cursor may continue to track the operator's motion and disappear from the display, leaving no indication to the operator of the location of the cursor and consequently causing some operator disorientation, or (2) the cursor may "stick", i.e. remain confined to the display, at, for example, point (1312). Conventional on-screen keyboards respond in this way. The operator's line of sight is now 20 degrees to the left of the cursor location. After the dwell period, the quadrant (1308) is selected and Figure 4 is displayed. The cursor hasn't moved. It is now at point (1320). Assume that again the operator attempts to point to the quadrant

containing the "j" key image (1324) in Figure 4. As the operator turns his head to the right, the cursor immediately moves with him. Thus, the operator's line of sight remains 20 degrees to the left of the cursor location as the cursor moves to the right across the display. The operator must watch the cursor out of his right eye. The problem is aggravated if either the operator cannot cleanly stop or if he drifts as he dwells. Assume that while attempting to dwell on quadrant (1324) the operator drifts 25 degrees past the bottom of the screen. His line of sight is now 25 degrees below and 20 degrees to the left of the cursor. To correct this misalignment in the conventional quaternary keyboard, the operator must turn his head to the right, "stick" the cursor against the right edge of the display, and continue turning 20 degrees until he has the cursor in his line of sight. Then he must lift his head until he sticks the cursor against the top edge and continue lifting 25 degrees more. Alternatively, in this scenario, the operator could stick the cursor in the upper right corner of the display and simultaneously rotate his head up and to the right until he brought the cursor into his line of sight.

Alignment is also a problematic for NMD operators who use a pointer, such as a mouse, with which the operator indicates by a location on a surface, e.g. a desk top, which corresponds to a desired location on the display, and achieve alignment by removing the pointer from the surface, e.g. lifting the mouse, moving the mouse, then replacing it on the surface. Due to impaired fine motor control, many NMD operators cannot remove a pointer from the surface and replace it on the surface at a desired location without unintentional movement or extraordinary effort. For these operators, alignment cannot be effectively achieved through conventional means.

In summary, misalignment interferes with accurate pointing and the process of correcting for misalignment may result in the selection of unintended key images.

One object of the invention is to allow an operator to align a pointer with a location on a surface.

Another object of the invention is to indicate to an operator a location on a surface with which he may align a pointer.

Still another object of the invention is to indicate to an operator when he may align a pointer with a location on a surface.

A further object of the invention is to allow an operator having impaired motor control to align a

pointer with a cursor.

G. Length Order

As noted previously, one of the elements determining the menu option selection time is the time the operator requires to comprehend the menu options displayed. This time may be reduced if the operator can limit the number of menu options he searches in looking for his desired menu option. Conventional word prediction systems attempt to reduce this operator search time. The operator of a conventional word prediction system may, for example, select the letter "p". The system displays some number, say six, of the most frequently used words beginning with the letter "p". Conventionally these seven words are displayed either in alphabetic order or in order of frequency of use. Assuming the operator does not see his desired word on the display, he selects another letter, say "r". The system then displays the six most frequently used words beginning with the letters "pr".

Searching a displayed list of words in alphabetic order requires that the operator focus his attention on the selection task, as opposed to the information content of the conversation or other task the operator is engaged in. Further, determining whether a given word is alphabetically greater or lesser than a desired word takes substantial time, slowing the selection process. An alphabetically ordered list is of limited use to an individual who has below normal spelling ability, a frequent problem among individuals with impaired speech. Ordering words by frequency of use often does not limit the number of words the operator must search. The word at the bottom of the displayed list, for example, the sixth most frequently used word beginning with the letters "pr" may be a very common word, even though it is less frequently used than the other five displayed words.

One object of the Length Order aspect of the invention is to reduce the time an operator requires to comprehend displayed menu options.

Another object of the Length Order aspect of the invention is to reduce operator search time.

Still another object of the Length Order aspect of the invention is to limit the number of menu options an operator searches for in looking for his desired menu option.

A further object of the Length Order aspect of the invention is to speed data entry.

Yet another object of the Length Order aspect of the invention is to increase productivity in speech synthesis for an operator having impaired speech.

H. Location Indication

The difficulties experienced by NMD operators in pointing to relatively small selectable regions have already been described. One approach to these difficulties is to enlarge the on-screen selectable region, illustrated by the quaternary expansion on-screen keyboard already described. Another approach is the conventional eye gaze system for a speech impaired individual, depicted in Figure 8. The system consists of a plexiglass frame (6352) having a centrally located aperture (6354). The eye gaze system is positioned between the speech impaired individual and person with whom the speech impaired individual is communicating. There are eight groups of five squares each on the plexiglass frame. Each square within each group of five squares is color coded, e.g. red, blue, green, yellow and clear, matching the color on each of the four corners of the plexiglass frame. The clear square matches the aperture (6354). All squares are labeled with symbols representing items to be communicated. These labels are not shown in Figure 8. The person with whom the speech impaired individual is communicating observes the eyes of the speech impaired individual to determine the target of the speech impaired individual's eye gaze. To communicate an item, the speech impaired individual gazes first toward the one of the eight groups of five squares, indicating that he wants to communicate one of the symbols in that group, and gazes second toward one of the four corners and aperture (6354) matching the color of the square labeled with the item to be communicated in the previously indicated group.

Two types of selectable regions are conventionally used in a point and click menu interface in a graphical user interface. The first, shown in Figure 9, depicts a menu having three menu options, labeled "High", "Medium" and "Low", each displayed on a display (4807), each associated respectively with selectable regions (4801), (4803) and (4805), and each located adjacent the associated selectable region. Figure 10 depicts a menu having the same three menu options, each displayed on a display (4807), each associated respectively with selectable regions (4901), (4903) and (4905), and each intersecting the associated selectable region. In both these conventional menus, a menu option is selected by pointing to and clicking on the associated selectable region.

Conventional menu hierarchies in automated systems, built from menus of the type shown in Figure 9 or Figure 10, require that the operator proceed sequentially through the steps of searching

menu options, selecting one of them, and, assuming a menu option including a submenu was selected, searching the submenu options, and selecting one of them. Where selection from menu hierarchies constitutes a substantial component of the operator's activities, the slowness of the selection process diminishes productivity.

Locating selectable regions or parts thereof outside the display, in accordance with the Perimeter Menu aspect of the invention, allows the large areas outside the display to be used, a major advantage for operators having impaired fine motor control who are unable to maintain a pointer on a small selectable region while selecting by click or by dwell. However, if menu options are displayed on the display near the perimeter of display and near their associated selectable region, the operator has an indication of the location of each selectable region but may not be able to see all the displayed menu options in a glance. Because an operator usually searches a displayed menu for his intended menu option, placing the menu only near the perimeter of the display may increase menu search time, thus increasing menu option selection time.

One object of the invention is to indicate to an operator of a menu system having selectable regions outside the display, the menu option associated with each selectable region and the location of each selectable region.

Another object of the invention is to facilitate selection from a menu by an operator having impaired motor control.

Still another object of the invention is to speed selection of a menu option from a menu and of a submenu option from a menu hierarchy.

A further object of the invention is to speed speech synthesis for a person having impaired speech and impaired motor control.

I. Sound Match

Conventional speech recognition systems facilitate computer access for individuals unable to use a standard keyboard whose speech is relatively unimpaired, for example, an individual with quadriplegia, and hands-free computer access for able-bodied individuals. The operator of such a speech recognition system reads a menu option out loud, for example, "open file", and the system.

which includes sound receiving means, for example, a microphone coupled to a sound board having a Digital Signal Processor ("DSP"), receives the sound of the read menu option, digitizes the sound of the read menu option, and then provides the digitized sound to another component of the speech recognition system, sound matching means which includes an application program for matching the digitized sound to one of a plurality of sounds, each representing respectively the sound of a spoken menu option. The system determines which sound best matches the sound of the read menu option and selects the menu option associated with this best matched sound.

Individuals whose speech is impaired are often unable to effectively use conventional speech recognition systems because they often cannot produce a large distinct variety of sounds characteristic of phonetic languages. For example, such an individual may produce similar sounds for the two consonants "t" and "d" so that these sound are indistinguishable to a conventional speech recognition system, or such an individual may not be able to consistently produce sounds distinguishable by a speech recognition system, resulting in false matches. Other symptoms of impaired speech, for example, similarities among certain phonemes and impaired ability to start or stop sound production appropriately, may substantially limit the variety of sounds distinguishable to a conventional speech recognition system an individual may consistently produce.

Conventional speech recognition systems provide limited capabilities in languages rich in homophones, for example, Chinese, because in such languages, a distinct sound is often insufficient to specify a word, as is described in the Background Art section of the Ideographic Languages aspect of the invention. The problem may be briefly illustrated by an example. Suppose a Chinese data entry operator using a conventional speech recognition system speaks the phonetic unit "fu" with a particular intonation. This distinct sound may well have over 15 homophones. Although the operator could use the keyboard to select one of these 15 homophones, this defeats the purpose of speech recognition, which is to facilitate hands-free computer access.

One object of the invention is to facilitate selection from a menu, and, in particular, from a menu of homophones.

Another object of the invention is to facilitate speech synthesis and voice activated computer access by individuals with speech impairments.

Still another object of the invention is to speed data entry in Ideographic Languages.

J. Ideographic Language

The use of ideographs as the graphic symbols in written languages is found in many parts of the world. An ideograph, as used herein, is a graphic symbol used to represent an object, an idea or a word, without expressing, as in a phonetic system, the specific sounds forming the verbal expression of the object, idea or word. Ideographic languages include Chinese, Japanese and Korean. A graphic symbol, as used herein, includes, but is not limited to, each of the following: a letter of an alphabet, a Japanese kana, and an ideograph. For purposes of illustrating the concepts of the present invention specific reference will be made herein to a preferred embodiment of the system and method as it applies to the Chinese language.

In modern Chinese, a repertoire of between 2500 and 3000 ideographs is necessary to achieve normal business adequacy in reading and writing, while the language itself has approximately 50,000 ideographs that have been identified historically, with about 10,000 ideographs in current use. The conventional keyboard, with approximately 100 keys, is designed for languages with phonetic scripts, such languages having a small set of graphic symbols, i.e. letters. If such a keyboard were to be used in a corresponding manner for the direct input of Chinese ideographs, it would require many thousands of keys since, unlike western phonetic languages, Chinese has many thousands of ideographs. Selection of an ideograph from such a keyboard would require the operator to search a great many keys for the desired key, and thus be impracticably slow.

Prior art methods for selecting Chinese ideographs make use of various ideograph classification systems known to Chinese speakers. The operator first specifies a class of ideograph, based on a first characteristic common to many ideographs. Ideographs having that common characteristic are displayed and the operator selects from among them, either directly, by selecting an individual ideograph, or indirectly, by specifying a second common characteristic usually dependent upon the first characteristic, thus further limiting the displayed ideographs to those having both the first and second common characteristics. In some prior art methods, the operator may continue to specify characteristics until he has specified a unique ideograph.

One ideograph classification system is called the Pin Yin System. This classification system uses the phonetic structure of the Chinese language. In spoken Chinese there are approximately 412 basic phonetic units, each having a monosyllabic sound, for example, "nee", "how" and "ma". Four intonations can potentially be applied to each phonetic unit, resulting in approximately 1280

distinct sounds. With 10,000 ideographs in current use, each represented by one of approximately 1280 distinct sounds, it is evident that many Chinese ideographs are homophones, i.e. have the same sound. Over 80% of Chinese ideographs have homophones. The Pin Yin System uses this limited number of phonetic units as the basis for its classification. Ideographs which are homophones are classified together; the common characteristic of the Pin Yin System is the distinct sound.

According to the Pin Yin and Zhu Yin coding methods, known in the prior art, the operator specifies a distinct sound using a keyboard labeled with symbols representing the Latin alphabet (Pin Yin method) or Chinese phonetic units (Zhu Yin method). The first key operation or sequence of key operations specifies the phonetic unit. The second key operation specifies the intonation. In general, less than 15 ideographs have this sound, though in some cases there are many more homophones. These are displayed and the user selects from among them. In such cases, the operator, depending upon the system, may page through matching ideographs or specify another common characteristic to further limit the number of ideographs displayed. A common characteristic which may be used at this stage exploits another feature of the Chinese language. The majority of Chinese words are expressed by a combination of two ideographs, the meaning of the paired ideographs has its own meaning which may or may not be related to that of the constituent ideographs. Assuming the operator has specified a first distinct sound matching 40 ideographs, he may specify a second distinct sound which alone may match, for example, 20 ideographs, but there may be only two ideograph pairs having the specified first and second distinct sounds in that order. Thus, a second common characteristic may limit matching ideograph pairs to a number sufficiently small for the operator to efficiently search and select from, or may uniquely specify an ideograph pair. Another common characteristic the operator may specify to limit the number of matching ideographs is a meaning or meaning class to which one or more sequences of one or more ideographs belong.

Yet another feature of the Chinese language which may be exploited to limit the number of matching sequences of ideographs is the ideograph block. An ideograph block is a sequence of four ideographs which together has its own meaning which may or may not be related to that of the constituent ideographs. As above, where the operator specified a distinct sound for the second of two ideographs of an ideograph pair, so may the operator specify a distinct sound for the second, third and/or fourth ideograph of an ideograph block, to limit the number of matching ideograph blocks.

Another conventional ideograph classification system makes use of a classification of parts of ideographs. Ideographs are built from a set of 214 components, called radicals. Different radicals, perhaps placed within different locations within an ideograph, are combined to create an ideograph. According to the Chan Jie coding method, known in the prior art, the operator specifies one or more radicals appearing in the ideograph he wishes to enter. He may, for example, use a keyboard having at least 214 keys, each corresponding to a radical, or may actuate a sequence of keys, the sequence corresponding to a radical. Other common characteristics the operator may specify to limit the number of matching ideographs include a phonetic unit, the first brush stroke, and the last brush stroke used to draw the ideograph.

Another conventional ideograph classification system makes use of a classification of parts of ideographs. According to the Four Corner coding method, known in the prior art, the operator specifies the classification of the four corners of the ideograph he wishes to enter. Other common characteristics the operator may specify to further limit the number of matching ideographs include the number of horizontal strokes used to draw the ideograph, and the classification of a certain part of the ideograph above the lower right corner.

Yet another conventional ideograph classification system makes use of a classification ideographs based on the basic strokes from which each ideograph is built. In Chinese, there are a limited number of basic strokes, each ideograph being composed of between 1 and 33 such strokes. Ideographs may be classified by a small number of basic strokes, preferably according to strict rules regarding the order of stroke entry. In one conventional application of this coding method, the operator specifies only the first and last basic strokes of the desired ideograph, then selects from a display of all ideographs sharing this first-last basic stroke combination.

Japanese is somewhat more complicated than Chinese. In addition to ideographs, the Japanese language uses graphic symbols called kana, which includes hiragana and katakana. In written Japanese, ideographs are frequently combined with kana. Kana may be may specified phonetically, for example, to designate the hiragana pronounced "ko" an operator of a Japanese word processing system may type "k" and then "o" on a Latin alphabetic keyboard or may type a single key associated with this hiragana. Kana has multiple uses in a Japanese word processing system. Kana may represent itself, since kana may stand alone in Japanese text. Alternatively, kana may be used to specify Japanese ideographs, either by specifying the radicals which compose Japanese ideographs or by specifying the pronunciation of Japanese ideographs. A sequence of phonetic

units specified by kana may represent that sequence of kana, a single Japanese ideograph, multiple Japanese ideographs, or a combination of one or more Japanese ideographs and one or more kana. In addition, a single Japanese ideograph may have multiple pronunciations, including a Japanese pronunciation and a Chinese pronunciation, and may have multiple kana spellings.

Conventional word processing systems for ideographic languages suffer from certain deficiencies. First, in systems where the operator specifies common characteristics until he has uniquely specified an ideograph, the operator must be extensively trained in the particular classification system. Depending upon the system, the operator may need to know, for example, how may horizontal brush strokes are required to draw a desired ideograph, or each of the 214 radicals and the encoding of each of them on a keyboard having less than 214 keys. Second, in systems where the operator uses both hands on the keyboard to specify a common characteristic, then selects from among ideographs, ideograph pairs or ideograph blocks by operating a function key or by pointing to one of the options with a mouse or other hand operated pointer and then operating a switch, the operator lifts one of his hands from the keyboard, makes the selection and then moves his hand back to the keyboard to specify another common characteristic. This sequence occurs often and contributes to the slow average rate of word entry (approximately 20 words per minute) for Chinese relative to alphabetic languages. Another problem in these systems is that the display of ideographs for selection may obscure part of the image of the previously entered ideographs or other information on the display.

Another drawback of many word processing systems for ideographic languages relates to the ease of copying a document. Ideally, the operator concentrates on the document to be copied, only occasionally scanning text he has input. For those word processing systems that display ideographs on a display for the operator's selection, the operator must frequently shift his gaze from the document to the display and back again. The operator cannot concentrate on both the document and the display simultaneously.

Ideographs, as used herein, also include the symbols of symbol sets used for communication by individuals who have hearing, speech or language impairments, for teaching literacy skills to those lacking them, including pre-literate children and individuals with intellectual disabilities, and for international written communication. These symbol sets include, but are not limited to, each of the following: Picture Communication Symbols, Rebus, Picsym, Pictogram Ideogram Communication Symbols, Yerkish, Blissymbolics and depictions of the signs of a manual sign language. Examples

of symbols of the Picture Communication Symbols, Rebus, Picsyms, and Blissymbolics symbol sets are shown in Figure 11, Pictogram Ideogram Communication Symbols in Figures 12(a) - 12(d) and Yerkish in Figures 13(a) - 13(j). Picture Communication Symbols, Rebus, Picsyms, Pictogram Ideogram Communication Symbols, Yerkish, and Blissymbolics are each described in Beukelman, David R. & Mirenda, Pat, Augmentative and Alternative Communication, Management of Severe Communication Disorders in Children and Adults, Paul H. Brookes Publishing Co., 1992, pp. 22-29.

Individuals who have not acquired or who have lost their literacy skills may use symbolic symbol sets in learning to read. If the individual lacks fine motor control, for example, due to cerebral palsy, the individual's disability may inhibit the acquisition of literacy skills by, for example, inhibiting repetition of an exercise by the individual, by limiting the individual's ability to participate in the classroom, or by making skill assessment by a teacher difficult so that the teacher may incorrectly believe that remediation is necessary or that a particular skill has been mastered. If the individual also has impaired speech, literacy acquisition is more difficult still.

Conventional literacy training systems for individuals who are unable to use a standard keyboard or mouse use switch access, often in combination with scanning. As already described, scanning is an extremely slow process. Moreover, as the number of symbols in the symbol set increases, the time required to select a symbol also increases. Of the symbol sets mentioned above, Picture Communication Symbols contains approximately 1800 symbols, Rebus contains approximately 800 symbols, Picsyms contains approximately 1800 symbols, Pictogram Ideogram Communication Symbols contains approximately 400 symbols and Blissymbolics contains approximately 1400 symbols. When using a system with a static display, the operator may expend considerable time and effort finding the desired symbol; when using a system with a dynamic display, the operator may expend considerable time effort memorizing and recalling where a particular symbol is located within a hierarchy of symbols. This time and effort generally does not contribute to the acquisition of literacy skills.

One object of the invention is to display a menu of sequences of one or more ideographs on a display so that a large contiguous area on the display is not obstructed by the menu.

Another object of the invention is to facilitate ideograph entry in word processing systems for the Chinese, Japanese and Korean languages.

Still another object of the invention is to speed selection of sequences of graphics including one or more ideographs.

Yet another object of the invention is to allow an operator of a word processing system for an ideographic language to select a sequence of one or more ideographs without lifting either hand from the keyboard.

A further object of the invention is to indicate to an operator the progress toward selection of a dwell-selectable sequence of one or more ideographic characters.

A still further object of the invention is to synthesize speech for an operator having impaired speech.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

Disclosure of Invention

A & B. Perimeter Menu and Confinement

According to the present invention, the objects mentioned in the Background Art section describing the above aspects of the invention and other objects and advantages are attained by an apparatus for selecting a menu option from a menu. Each menu option is associated respectively with a selectable region on a display area. The apparatus includes (a) the display area; (b) means for delimiting a plurality of selectable regions, each of the selectable regions associated respectively with a menu option and each of the selectable regions including an invisible subregion adjacent the display area and a visible subregion on the display area, the plurality of visible subregions together at least partially circumscribing a region on the display area; (c) movement related signal receiving means for receiving a movement related signal indicating a location; and (d) selection means for

selecting, in response to a selection event, the menu option associated with the selectable region intersected by the location indicated by the movement related signal.

Additionally, the objects mentioned in the Background Art section describing the above aspects of the invention and other objects and advantages are attained by a method of selecting a menu option from a menu. The menu options are each respectively associated with a selectable region on a surface which includes a display area. The selectable regions together at least partially circumscribe a region on the display area. An operator indicates a location on the surface with a body member. The method comprises the steps of: (a) confining the location indicated by the body member of the operator to the display area; and (b) selecting, in response to the period of one or more intersections of the location indicated by the movement related signal and any one selectable region equalling or exceeding a predetermined period, the menu option associated with the intersected selectable region.

The method and apparatus of the aspect of the invention disclosed above and other aspects of the invention permits an NMD operator to utilize for computer access his relatively unimpaired motor capabilities, in particular, gross motor control, in lieu of, or as a supplement to, his impaired motor capabilities. The method and apparatus of the invention also reduces the interference of menu option displays with the display of information.

C. Dwell

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for indicating dwell time comprising a surface having a region thereon; movement receiving means for receiving a movement related signal indicating successive locations; and indicating means for indicating at least the duration of a period of intersection of two or more of the successive locations indicated by the movement related signal and the region.

Additionally, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by a method of indicating dwell time comprising the steps of displaying a selectable region on a surface; receiving a movement related signal indicating a first location intersecting the region and, at a later time, a second location intersecting the region; and indicating the difference between the time of the second location and

the time of the first location.

D. Path Directness

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for selecting a menu option from a menu. Each menu option is associated respectively with a selectable region shown on a surface. The apparatus includes (a) means for moving a cursor on the surface in response to a movement related signal, for example, a computer program which moves a cursor on the surface reflecting the operator's movement of a mouse; and (b) means for selecting the menu option associated with the selectable region most nearly along a cursor path (1) prior to an intersection of the cursor and the selectable region most nearly along the cursor path, (2) upon intersection of the cursor and the selectable region most nearly along the cursor path, or (3) in response to the period of intersection equalling or exceeding a predetermined period.

Also according to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained by a method for selecting a menu option from a menu. Each menu option is associated respectively with a selectable region shown on a surface. The method includes the steps of (a) displaying the selectable regions on the surface, (b) detecting a movement related signal and in response moving a cursor on the surface, and (c) selecting the menu option associated with the selectable region most nearly along a cursor path (1) prior to an intersection of the cursor and the selectable region most nearly along the cursor path, (2) upon intersection of the cursor and the selectable region most nearly along the cursor path, or (3) in response to the period of intersection equalling or exceeding a predetermined period.

In accordance with the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for measuring an individual's ability to move one of the individual's body members directly from a starting position to an ending position. The apparatus includes: (a) receiving means for receiving a sampling among data indicative of successive positions of the body member; and (b) measurement means for measuring any deviation of the path indicated by the received position data from a direct path between the starting position and the ending position.

The objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained, according to the present invention, by a method for measuring an individual's ability to move one of the individual's body members directly from a starting position to an ending position. The method includes the steps of: (a) receiving a sampling among data indicative of successive positions of the body member; and (b) measuring any deviation of the path indicated by the received position data from a direct path between the starting position and the ending position.

E. Intersection

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for selecting an option from a menu. The apparatus comprises cursor movement means for receiving a movement related signal and for moving a cursor on a display responsive to the received movement signal; delimit means for delimiting with respect to the display a first plurality of regions and a second plurality of selectable regions, each of the first plurality of regions associated respectively with one of the second plurality of selectable regions, each of the second plurality of selectable regions associated respectively with a menu option, wherein at least one of the first plurality of regions is not coterminous with its associated one of the second plurality of selectable regions; and selection means, responsive to an intersection of the cursor and any one of the first plurality of regions and to a selection event associated with the one of the second plurality of selectable region associated with the intersected one of the first plurality of regions, for selecting the menu option associated with the selectable region associated with the selection event.

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained by a method of selecting an option from a menu, said method comprising the steps of: receiving a movement related signal and moving a cursor on a surface responsive thereto; delimiting a first plurality of regions and a second plurality of selectable regions with respect to a surface, each of the first plurality of regions associated respectively with one of the second plurality of selectable regions, each of the second plurality of selectable regions associated respectively with a menu option; wherein at least one of the first plurality of regions is not coterminous with its associated one of the second plurality of selectable regions; and responsive to an intersection of the cursor and any one of the first plurality of regions and to a selection event associated with the one of the second

plurality of selectable region associated with the intersected one of the first plurality of regions, selecting the menu option associated with the selectable region associated with the selection event.

F. Alignment

Confining the cursor to the display or to a polygon on the display, in accord with the Perimeter Menu aspect of the invention, facilitates selection from a perimeter menu. However, for an operator who overshoots a perimeter menu option, confining the cursor to the display results in a loss of alignment between the cursor and the location indicated by the operator, necessitating an apparatus and method for realignment.

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus, including a surface on which may be displayed a moveable cursor, said apparatus allowing an operator to align a pointer with a predetermined location on the surface. The apparatus includes a display means for displaying the cursor on the surface; movement related signal receiving means for receiving a movement related signal; and control means for moving the cursor in response to the movement related signal and for thereafter inhibiting movement of the cursor for a first period of time in response to an operator action detected by the movement related signal receiving means.

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained by a method, for use in a system comprising a pointer and a surface on which is displayed a first cursor whose movement on the surface is responsive to the movement of the pointer, of aligning the first cursor with a predetermined location on the surface. The method includes the steps of: (a) producing the first cursor on the surface; (b) moving the first cursor responsive to the movement of the pointer, said movement restricted to a region on the surface; and then (c) responsive to an operator action, producing a second cursor at a predetermined location on the surface for a period of time; and (d) moving the first cursor in or in close proximity to the predetermined location..

G. Length Order

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for

use in a menu interface system. The apparatus orders a plurality of named menu options at least in part according to the order of the length of each of the names of the name menu options, and then displays the named menu options in that order

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained by a method of data entry for use with a computer. According to the method, a plurality of named menu options are displayed at least in part according to the order of the length of each of the names of the name menu options. Each named menu option is associated respectively with a sequence of one or more characters. A selection event is associated with one of the named menu options and the sequence of one or more characters associated with the selected named menu option is input to an application program executing on the computer.

H. Location Indication

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for indicating the location of the selectable region associated with a menu option. Each menu option is associated respectively with a selectable region. The apparatus includes (a) means for at least partially delimiting the selectable regions; and (b) indication means for displaying each menu option such that the displayed menu option indicates the location of the associated selectable region. None of the displayed menu options intersects the selectable region associated therewith.

According to the present invention, some of the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained by a method of indicating the location of the selectable region associated with a submenu option in a menu hierarchy. The method comprises the steps of: at least partially delimiting the plurality of selectable regions; and displaying a plurality of submenu indicating regions. Each submenu indicating region is associated respectively with one of the submenu options and each submenu indicating region is displayed in a manner indicating the location of the selectable region associated with the submenu option associated with the submenu indicating region.

I. Sound Match

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by an apparatus for selecting a menu option from a plurality of menu options. Each menu option is displayed on a display and associated respectively with a sound. The apparatus includes: (a) means for displaying the menu on the display; (b) means for receiving a sound signal; (c) means for matching the received sound signal to any one of sounds; and (d) means for selecting the menu option associated with the matched sound.

According to the present invention, some of the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are also attained by a method of selecting a sequence of one or more graphic symbols from a plurality of sequences of one or more graphic symbols, one or more sequences of the plurality of sequences including one or more ideographs. The method comprises the steps of displaying on a display the plurality of sequences, each of the plurality of sequences having a common characteristic and each associated respectively with a sound indicator; matching a sound to any one of the plurality of sound indicators; and selecting the sequence of the plurality of sequences associated with the matched sound indicator.

J. Ideographic Languages

According to the present invention, the objects mentioned in the Background Art section describing the above aspect of the invention and other objects and advantages are attained by a method for selecting a single sequence of one or more ideographs from a menu of several such sequences. Each sequence is respectively associated with a selectable region on a surface which includes a display area. The selectable regions together at least partially circumscribe a region on the display area. An operator indicates a location on the surface with a body member. The method comprises the steps of: (a) displaying the selectable regions on the surface so that they at least partially circumscribe a region on the display area; and (b) selecting, in response a selection event, the sequence indicated by the operator.

Still other objects and advantages of the present invention will become readily apparent to those skilled in this art from the following detailed descriptions, wherein I have shown and described the preferred embodiment of each aspect of the invention, simply by way of illustration of the best mode contemplated by me of carrying out each aspect of my invention. As will be realized, each

aspect of the invention is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the invention. Accordingly, the drawings and descriptions are to be regarded as illustrative in nature, and not as restrictive.

Brief Description of Drawings

FIG. 1 is an illustration of a display showing a conventional on-screen keyboard.

FIG. 2 is an illustration of a display showing a conventional on-screen keyboard and output from a word processing application program.

FIG. 3, 4 and 5 are each illustrations of the display of each step of letter selection using a conventional quaternary on-screen keyboard.

FIG. 6 is an illustration of a display showing a conventional quaternary on-screen keyboard and output from two application programs.

FIG. 7 is an illustration of a conventional device implementing joystick patterns.

FIG. 8 is an illustration of a display of a conventional eye gaze system.

FIG. 9 and 10 are each illustrations of a display showing a conventional menu.

FIG. 11 depicts examples of symbols from the Picture Communication Symbols, Rebus, PicSym and Blissymbols symbol sets.

FIG. 12(a) - FIG. 12(d) depict examples of symbols from the Pictogram Ideogram Communication Symbols symbol set.

FIG. 13(a) - FIG. 13(j) depict examples of symbols from the Yerkish symbol set.

FIG. 14 is a block diagram of a computer which may be utilized in accordance with the present

invention.

FIG. 15 is a block diagram of a speech synthesis system which may be utilized in accordance with the present invention.

FIG. 16 is an illustration of software components of an apparatus in accordance with an embodiment of the Perimeter Menu aspect of the invention.

FIG. 17 and 18 are each illustrations of a display and structures in accordance with an embodiment of the Perimeter Menu aspect of the invention.

FIG. 19 is an illustration of a display and structures in accordance with another embodiment of the Perimeter Menu aspect of the invention.

FIG. 20 is an illustration of a display and structures in accordance with still another embodiment of the Perimeter Menu aspect of the invention.

FIG. 21 is an illustration of a display and structures in accordance with another embodiment of the Perimeter Menu aspect of the invention.

FIG. 22 is an illustration of a display and structures in accordance with yet another embodiment of the Perimeter Menu aspect of the invention.

FIG. 23 is an illustration of an apparatus in accordance with a further embodiment of the Perimeter Menu aspect of the invention.

FIG. 24 and 25 are each illustrations of a display and structures in accordance with another embodiment of the Perimeter Menu aspect of the invention.

FIG. 26 and 27 illustrate an apparatus in accordance with still another embodiment of the Perimeter Menu aspect of the invention. Figure 26 depicts a front view of the apparatus. Figure 27 depicts a cut away view from the top of the apparatus.

FIG. 28 is a top view of a headrest in accordance with an embodiment of the Perimeter Menu

aspect invention.

FIG. 29 and 30 illustrate the state table aPocketFsm in accordance with the preferred embodiment of the Perimeter Menu aspect of the invention.

FIG. 31 is an illustration of a display and structures in accordance with the preferred embodiment of the Confinement aspect of the invention.

FIG. 32 is an illustration of a display and structures in accordance with another embodiment of the Confinement aspect of the invention.

FIG. 33 is an illustration of a display and structures in accordance with another embodiment of the Confinement aspect of the invention.

FIG. 34 is an illustration of an apparatus in accordance with the Dwell aspect of the invention and with the Path Directness aspect of the invention.

FIG. 35 is an illustration of another apparatus in accordance with the Dwell aspect of the invention.

FIG. 36 is an illustration of still another apparatus in accordance with the Dwell aspect of the invention.

FIG. 37 is an illustration of yet another apparatus in accordance with the Dwell aspect of the invention.

FIG. 38 is an illustration of another apparatus in accordance with the Dwell aspect of the invention.

FIG. 39 is an illustration of a display and structures in accordance with the preferred embodiment of the Path Directness aspect of the invention.

FIG. 40 is an illustration of a display and structures in accordance with an embodiment of the Path Directness aspect of the invention.

FIG. 41 is an illustration of a display and structures in accordance with another embodiment of the

Path Directness aspect of the invention.

FIG. 42 is an illustration of a display and structures in accordance with another embodiment of the Path Directness aspect of the invention.

FIG. 43 is an illustration of a display and structures in accordance with another embodiment of the Path Directness aspect of the invention.

FIG. 44. 45 and 46 are each illustrations of a display and structures in accordance with the preferred embodiment of the Intersection aspect of the invention.

FIG. 47 and 48 are each illustrations of a display and structures in accordance with another embodiment of the Intersection aspect of the invention.

FIG. 49, 50 and 51 are each illustrations of a display and structures in accordance with the preferred embodiment of the Alignment aspect of the invention.

FIG. 52 is an illustration of a display and structures in accordance with the preferred embodiment of the Location Indication and the Length Order aspects of the invention.

FIG. 53 is an illustration of a display and structures in accordance with an embodiment of the Location Indication aspect of the invention.

FIG. 54 and 55 are each illustrations of a display and structures in accordance with another embodiment of the Location Indication aspect of the invention.

FIG. 56 is an illustration of a display and structures in accordance with a still further embodiment of the Location Indication aspect of the invention.

FIG. 57 is an illustration of a display and structures in accordance with a further embodiment of the Location Indication aspect of the invention.

FIG. 58 and 59 are illustrations of a display and structures in accordance with the preferred embodiment of the Sound Match aspect of the invention.

FIG. 60 is an illustration of a display and structures in accordance with another embodiment of the Sound Match aspect of the invention.

FIG. 61 is an illustration of a display and structures in accordance with another embodiment of the Sound Match aspect of the invention.

FIG. 62 is a block diagram of a speech recognition system which may be utilized in accordance with the Sound Match aspect of the invention.

FIG. 63 is an illustration of software components of an apparatus in accordance with an embodiment of the Sound Match aspect of the invention.

FIG. 64 is an illustration of a display and structures in accordance with the preferred embodiment of the Ideographic Language aspect of the invention.

FIG. 65 is an illustration of a display and structures in accordance with another embodiment of the Ideographic Language aspect of the invention.

FIG. 66 is an illustration of a display and structures in accordance with still another embodiment of the Ideographic Language aspect of the invention.

FIG. 67 is an illustration of a display and structures in accordance with yet another embodiment of the Ideographic Language aspect of the invention.

Best Mode for Carrying Out the Invention

The hardware and software operating environment of the preferred embodiment of all aspects of the invention will now be described with reference to a particular embodiment of the invention, hereinafter "prototype". The prototype of the invention illustrates the best mode of practicing each aspect of the invention known by me except where a preferred mode is described.

Figures 15 depicts a block diagram of the hardware components of the prototype (2214), including a conventional general purpose computer system (2218), an optional pointer (2202), an optional

printer (2220) and a speech synthesizer (2206). The general purpose computer system (2218) includes a conventional computer system (2116), a storage unit (2208), a keyboard (2210), and a diskette drive (2216). Figure 14 depicts a block diagram of the conventional computer system (2116), including a processing unit (2102) and a display (2112). The processing unit (2102) includes a processor (2104), a memory (2106) and control circuitry (2108). The prototype employs the Toshiba T6400DXC general purpose computer system manufactured by Toshiba Corporation, Kawasaki, Japan. However, the T6400DXC is preferably substituted with the IBM ThinkPad 755C computer system, part number 9545F0C, manufactured by IBM Corporation, Armonk, New York, USA, because the former requires a 110VAC power source while the latter is powered by an integral battery. An integral battery allows an NMD operator to use the system when a 100VAC source is not available or when attaching to a 110VAC power source is inconvenient. The prototype further includes a head mounted pointer communicating via an infrared link with the computer system so that there are no cables tethering the operator to the computer system. Any cable between the operator and the computer system would have to be connected, probably by an attendant since the operator may lack the fine motor skills required to make such a connection. Preferably computer access can be accomplished independently by the operator. The choice of a pointing device is primarily dictated by the particular capabilities of the operator. Usually the best pointing device for a particular operator is the one drawing on that operator's best motor control. For example, if an operator's foot control is superior to his head control, a pointing device using his foot is preferably to a head pointer.

The prototype employs the Remote Headmaster® manufactured by the Prentke Romich Company, Wooster, Ohio, USA. However, the combination of the HeadMaster® Plus, part number HM-1P, HeadMaster® Plus Remote Adapter, part number HM-RA, and HeadMaster® Plus Laptop Adapter, part number HM-LA, all available from the Prentke Romich Company, is preferable because the headset is more comfortable and the HeadMaster® Plus ultrasonic transmitter mounts more easily on a laptop computer system than the Remote Headmaster ultrasonic transmitter.

The preferred embodiment further includes a battery powered printer, the MobileWriter®, part number 730879, manufactured by Mannessmann Tally Corporation, Kent, Washington, USA and a speech synthesizer, the Multivoice Speech Synthesizer, part number MV2-SS, manufactured by The Institute on Applied Technology, Children's Hospital, Boston, Massachusetts, USA.

The pointer (2202) is a device which provides data concerning the relative or absolute position of

the operator or any body member of the operator. The display (2112) and pointer (2202) together provide for the interactive nature of the general purpose computer system (2218) in that, in accord with the various aspects of the invention, the interpretation that the processor (2104) gives to a certain pointer action made by the operator depends, in the majority of situations, upon what is being displayed to the operator at that time.

The prototype (2214) shown in Figure 15 further includes a keyboard (2210), which functions to provide input from an able-bodied operator to the general purpose computer system (2218). The keyboard (2210) is useful for configuration, diagnostic and backup purposes, functions which are performed relatively infrequently and usually require an able-bodied person for ancillary activities, for example, loading backup media into the general purpose computer system. The prototype (2214) also optionally includes a printer (2220) which functions to provide hard copy output of data developed or stored in the general purpose computer system, and a speech synthesizer (2206), which functions to provide speech output for utterances and words composed using or retrieved from the general purpose computer system (2218).

The couplings between the devices depicted in Figure 15 may be made by any means which permits the orderly and timely exchange of data across the interface. In the preferred embodiment, the interfaces between the pointer (2202) and the general purpose computer system (2218) and between the general purpose computer system (2218) and the speech synthesizer (2206) conform to the Electronic Industries Association RS-232 interface specification. The interface between the general purpose computer system (2218) and the printer (2220) conform to the Centronix 50 pin parallel interface specification.

The software component of the prototype are stored in memory (2106) and executed on the processing unit (2102). The software component of the prototype, depicted in Figure 16, include a software driver (1202), an operating system (1204), an optional database program (1210), and the prototype access program code and data, hereinafter collectively referred to as the "access program" (1206). In the preferred embodiment, one or more application programs (1208) may also execute on the processing unit (2102) and accept control and data from the access program (1206) via the operating system (1204). The software driver (1202) of the prototype is the Logitech Mouse Driver included with Windows® version 3.1. The operating system (1204) of the prototype is Windows® version 3.1 in combination with MS-DOS® version 6.2. Hereinafter, the operating system is referred to simply as "Windows®", available from Microsoft Corporation, Redmond.

Washington, USA.

The optional database program (1210) is described in the detailed description of the Length Order aspect of the invention. The prototype access program (1206) is described in detail below.

As stated earlier, the software components of the prototype are stored in memory (2106). Depending on the capacity of memory (2106) and the size of the application programs, portions of these programs may be transferred as needed between memory (2106) and the storage unit (2206) or between memory (2106) and a diskette in the diskette drive (2216) depicted in Figure 15. The basic function of the storage unit (2206) and the diskette drive (2216) is to store programs and data that are employed by the general purpose computer system (2218) and which may readily be transferred to the memory (2106) when needed.

It is to be understood that components others than those used in the prototype may be utilized in accordance with the invention. It is only necessary that the substitute component or components have the capacity to carry out the functions described. For example, the processing unit of the general purpose computer system may be substituted with a microprocessor coupled to custom electronics for performing the functions of the various aspects of the invention, or the color display of the prototype may be substituted with a monochrome display.

A. Perimeter Menu

The preferred embodiment of the Perimeter Menu aspect of the invention will now be described in detail from a functional perspective using an example. This description refers to selectable regions which include one or more subregions. A selectable region is a region, delimited with respect to a display or a surface, and associated with a menu option which may be selected, usually by a selection event. A subregion is a selectable region that is included within another selectable region. Thus a subregion is, by itself, a selectable region. Assuming that a certain selectable region includes subregions A and B, dwell time on subregions A and B may be combined, for example, by summing, so that dwelling on either subregion A or B or a combination of both for the selection threshold period selects the menu option associated with the selectable region.

Reference will now be made to Figures 17 and 18 which depict an example of the preferred embodiment of the Perimeter Menu aspect of the invention. Figure 17 shows the display (2112) of

a general purpose computer system (2218 in Figure 15) and eight selectable regions. Each of the eight selectable regions consists of the union of a visible subregion on the display (2112) and an invisible subregion located outside the display (2112) and adjacent the visible subregion. For example, the selectable region at 11 o'clock in Figure 17 labeled with menu option "vort<space>x" consists of invisible subregion (0104) and visible subregion (0106), and within this description of the Perimeter Menu aspect of the invention is referred to as selectable region (0104/0106). The other selectable regions shown in Figure 17, proceeding counter clockwise from selectable region (0104/0106) are (0108/0110), (0112/0114), (0116/0118), (0120/0122), (0124/0126), (0128/0130) and (0132/0134). Each subregion may be sized to suit the operator's preferences and abilities. Each selectable region is associated respectively with a menu option. In Figure 17, selectable region (0104/0106) is associated with menu option vort<space>x, selectable region (0108/0110) with menu option "sumac", selectable region (0112/0114) with menu option "wizen'", selectable region (0116/0118) with the menu option undo indicated by an icon on visible subregion (0118) representing an undo function, selectable region (0120/0122) with menu option "words", selectable region (0124/0126) with menu option "talk", selectable region (0128/0130) with menu option "ldhbfk" and selectable region (0132/0134) with menu option "ypgqj,". Together, the eight visible subregions circumscribe region (0150) on the display.

Selectable regions may be delimited by data indicative of one or more boundaries of the selectable region. Equivalently, the delimit means may be detectors operative to determine when the location indicated by the movement related signal has crossed one of those boundaries or intersects a selectable region. A partially delimited region or subregion is one which is unbounded on at least one side.

Resuming, now, with the example, to select a menu option associated with a selectable region the operator moves a pointer (2202 in Figure 15) coupled to the general purpose computer system (2218 in Figure 15) to indicate a location on the selectable region, including either subregion, associated with the desired menu option and maintains the indicated location on the selectable region for the selection threshold period. The period of time required for selection may vary responsive to the proximity of the indicated location to the location of a cursor on the display or to the proximity of the indicated location to a point within the intersected selectable region. Dwell time may be continuous, discontinuous or dynamic (described below) for either or both subregions of the selectable region.

Selection in the above example is in response to a dwell event. A dwell event includes, but is not limited to, each of the following: (a) the durations of one or more periods of intersection of locations indicated by a movement related signal, a body member or a cursor (including any part of the cursor) and a selectable region equalling or exceeding a predetermined period; (b) a first quantity responsive to the durations of the periods referred to in (a) equalling or exceeding a predetermined quantity; (c) dwell event (a) or (b) followed by a location indicated by the movement related signal, the body member or the cursor no longer intersecting the intersected selectable region; and (d) dwell event (a) or (b) wherein the period of intersection required for selection of a selectable region increases in response to a non-intersection or a period of non-intersection of locations indicated by the movement related signal, the body member or the cursor and the selectable region ("dynamic dwell event"). The use of non-intersection or a period of non-intersection in determining the duration of a period of intersection required for selection is called dynamic dwell. Associated with each type of dwell event is an intersected selectable region. This is the selectable region intersected by the location indicated by the movement related signal, body member or cursor which triggers the dwell event by causing the period or the first quantity to equal or exceed the predetermined period or the predetermined quantity, respectively.

Selection may also be in response to a selection event. A selection event includes, but is not limited to: (a) a dwell event; (b) a switch operation at or near the time of an intersection of a location indicated by a movement related signal, a body member or a cursor and a selectable region; (c) an intersection of a location indicated by a movement related signal, a body member or a cursor and a selectable region; and (d) selection event (c) followed by a location indicated by the movement related signal, the body member or the cursor no longer intersecting the selectable region it previously intersected. Associated with each type of selection event is an intersected selectable region. This is the selectable region intersected by the location indicated by the movement related signal, body member or cursor. The fact that a selection event has occurred may be indicated to the operator, for example, visually by changing the cursor appearance or location, by changing location, size, shape, hue, brightness, contrast, tone, dithering, pattern, hatching, font or fill of an object on the surface, or by displaying a graphic or a point distinguishable from its immediate surroundings on a surface or removing a graphic or point distinguishable from its immediate surroundings from a surface; auditively by generating a sound or changing the pitch or volume of an extant sound; tactilely by changing the surface or temperature of a contact area or the pressure exerted by a contact area; or by other means. In the prototype, following selection, the hue of the visible subregion of the selected selectable region is changed from green to magenta.

As used herein, a cursor includes a temporary marking on a display which emphasizes to an operator, in an optical manner, a momentarily important location or object. As used herein, body member means any part of the body including, but not limited to, each of the following: the shoulder, arm, elbow, wrist, hand, finger, thumb, leg, knee, ankle, foot, toe, hip, trunk, neck, tongue, lip, eye and head. The received movement related signal includes, but is not limited to, a signal indicative of movement or from which movement can be derived, such as a plurality of relative or absolute positions or a difference between two relative or absolute positions. Movement related signal receiving means includes, but is not limited to, each of the following: (a) pointer interface circuitry found in a general purpose computer system; (b) one or more detectors operative to detect movement of a pointer; and (c) one or more detectors operative to detect movement of a body member of an operator. In the prototype, the movement related signal receiving includes electronic circuitry in the general purpose computer system (2218) operative to receive the movement related signal generated in part by the movement of the pointer (2202).

In the prototype subregions are displayed on the display (2112). However, other means for displaying may be substituted for the means used in the prototype, for example, a projector for projecting an image, a surface having a static display thereon, or other suitable means.

Resuming, now, with the example of Figure 17, and assuming that the operator has selected menu option "vort<space>x", the display is changed to that shown in Figure 18. In Figure 18, each of six selectable regions is now associated with a submenu option of the selected menu option "vort<space>x". Selectable region (0104/0106) is now associated with submenu option "<space>", selectable region (0108/0110) with submenu option "o", selectable region (0112/0114) with submenu option "t", selectable region (0124/0126) with submenu option "x", selectable region (0128/0130) with submenu option "v", and selectable region (0132/0134) with submenu option "r". Selectable regions (0116/0118) and (0120/0122) remains associated with the same menu options with which each was associated in Figure 17. The operator may now select one of these submenu options.

Assuming that the selected submenu option is one of v, o, r, t, x and space, the selected character, or a corresponding computer encoding of that character, may be input to an apparatus coupled to the general purpose computer system (2218 in Figure 15), or input to an application program (1208) executing on the general purpose computer system (2218) coupled to the display (2112). Inputting, as used herein, includes, but is not limited to, generating or passing signals

representative of the selected menu option along a path toward the destination apparatus or program. Preferably, the computer program displays at least some of its output in the circumscribed region (0150).

Given a display having eight selectable regions, an operator may, with a single selection indicate one of eight menu options, with two selections indicate one of up to 64 different menu options, with three selections indicate one of up to 256 menu options, etc. Each of these menu options may represent a sequence of one or more characters, a sequence of one or more data or control inputs to an application program (1208), or a control function for one or more devices or speech synthesizers coupled to the general purpose computer system (2218). As used herein, a character includes a space, a control character as defined by the American National Standards Institute (ANSI) or the American Standard Code for Information Exchange (ASCII), and a letter from one of the Afrikaans, Albanian, Amharic, Arabic, Armenian, Assamese, Assyrian, Avar, Azerbaijani, Balinese, Bamara, Bantu, Bashkir, Basque, Bengali, Birhari, Bulgarian, Buluba-Lulua, Burmese, Buryat, Byelorussian, Caddoan, Catalan, Chechen, Chikaranga, Chippewa, Choctaw, Church Slavik, Chuvash, Coptic, Cree, Croatian, Cyrillic, Czech, Dakota, Danish, Dari, Devanagari, Dutch, Dzongkha, English, Eskimo, Esperanto, Estonian, Ewe, Farsi, Fijian, Filipino, Finnish, Flemish, French, Fulani, Gaelic, Galician, Georgian, German, Greek, Gujarati, Gurmakhi, Harari, Hausa, Hawaiian, Hebrew, Hindi, Hiragana, Ibo, Icelandic, Indonesian, Irish, Irogquoian, Italian, Kabardian, Kalmyk, Kannada, Kanuri, Kashmiri, Katakana, Kazakh, Khasi, Khmer, Kirghiz, Kishmiri, Komi, Kongo, Kurdish, Lao, Latin, Latvian, Lithuanian, Lu-Guanda, Macedonian, Magahi, Maithili, Makua, Malagasy, Malay, Malayalam, Maltese, Mandingo, Manipuri, Marathi, Masai, Mizo, Moldavian, Mongolian, Munda, Naga, Navaho, Nyanja, Nepalese, Norwegian, Oriya, Oromo, Ossetian, Pashto, Polish, Portugese, Punjabi, Rajasthani, Rhaeto-Romanic, Rumanian, Russian, Samoan, Sangs, Serbian, Serbo-Croatian, Sinhalese, Sinhi, Sioux, Slovak, Slovenia, Spanish, Sundanese, Swahili, Swedish, Syriac, Tadzhik, Tagalog,Tajik, Tamil, Tatar, Telugu, Thai, Tibetan, Turkish, Turkmen, Udmurt, Uighur, Ukranian, Umbundu, Urdu, Uzbek, Vietnamese, Visayan, Welsh, Yakut, Yoruba and phonetic alphabets. As used herein, each of a character, ideograph, control input and control function includes a computer encoding of the same. As used herein, a device includes, but is not limited to, each of a wheelchair, a household appliance, an appliance for use in an office, a workstation, a robot, and a computer peripheral. Thus, by selecting from a menu, the operator may, for example, increase the volume of an external speech synthesizer, or turn a wheelchair to the left.

The selectable regions organized as described above help an NMD operator make the menu selection he intends. Referring to Figure 17, suppose, for example, an NMD operator intends to move a pointer (2202) that is indicating point (0154) to indicate point (0156), a location in subregion (0130), but who is unable to quickly stop motion, so that the location indicated by the pointer (2202) moves from point (0154) past point (0156) to point (0158). Because point (0158) lies within the same selectable region (0128/0130) as the overshot subregion (0130), dwelling at point (0158) operates to select the intended selectable region (0128/0130). Invisible subregions, in accordance with the Perimeter Menu aspect of the invention, may extend outward from the edge of the display (2112) to infinity. In such an embodiment, dwelling at point (0162) would operate to select selectable region (0128/0130). Preferably, invisible subregions extend a finite distance from the edge of the display (2112). In such an embodiment, dwelling at point (0162) would not operate to select selectable region (0128/0130). The sizes of the invisible subregions shown in Figures 17 and 18 are illustrative only. Preferably the size of each invisible subregion is large enough to encompass overshoot but small enough to avoid unintentional selections when the NMD operator turns to see someone or something.

The prototype utilizes the area outside the display to facilitate menu selection by a disabled operator. If an operator has impaired ability to maintain a steady position, he can point to a relatively large invisible subregion outside the display which is more forgiving of the operator's involuntary motion than the relatively small selectable regions on the display in conventional on-screen keyboards. Thus, the effective area of a selectable region is expanded beyond the region's visible subregion shown on a display. If an operator has impaired ability to stop motion he may, starting from the center of the screen, point to any selectable region. His impaired ability to stop will not impair his ability to select his intended target, assuming his directional control is relatively unimpaired, since, in the prototype, each selectable region is unbounded on its side furthest from the center of the display. Although the selectable regions of the prototype are large, only the visible subregion of each selectable region uses space on the display. Thus a large rectangular region remains available on the display for the output of an application program. The Perimeter Menu aspect of the invention is preferably implemented on a general purpose computer system. If the general purpose computer system is coupled to a speech synthesizer and the menu hierarchy allows the selection of letters and/or words, an operator having impaired speech may speak using the speech synthesizer. If a word processing or data entry application program is run on the general purpose computer system, the operator may enter words or data, respectively, for input to the application program. If the general purpose computer system is coupled to a devices capable of

executing commands and the menu hierarchy allows the selection of commands, a disabled operator may select and issue commands to control these devices.

Since the cognitive demand for scanning is greater than that for direct selection, the prototype places less cognitive demand on the operator than a scanning system for selecting options from a menu.

Figure 19 illustrates a display in accordance with an alternative embodiment of the Perimeter Menu aspect of the invention having eight selectable regions circumscribing a central region (6950) on the display.

Figure 20 illustrates a display in accordance with an embodiment of the Perimeter Menu aspect of the invention having twenty selectable regions circumscribing a central region (0806) on the display.

Figure 21 illustrates a display in accordance with an embodiment of the Perimeter Menu aspect of the invention having four selectable regions (0508), (0506), (0504) and (0502) circumscribing a central region (0510) on the display.

Figure 22 illustrates a display in accordance with an embodiment of the Perimeter Menu aspect of the invention having four selectable regions (4008), (4006), (4004) and (4002) with no space between them other than a circumscribed region (4010) on the display.

Figure 23 illustrates an apparatus in accordance with of another embodiment of the Perimeter Menu aspect of the invention. In Figure 23, region (3510) is located on interior display (3514) which is circumscribed by peripheral display (3512). Selectable regions (3508), (3535), (3504) and (3502) are located on the peripheral display (3512).

Figures 24 and 25 are each illustrations of a display and structures in accordance with another embodiment of the Perimeter Menu aspect of the invention. Figure 24 depicts ten selectable regions (6502), (6504), (6506), (6508), (6510), (6512), (6514), (6514), (6516), (6518), and (6520). Each selectable region is located on the display (2112) adjacent the edge of the display and associated respectively with a menu option. In Figure 24, the menu options are shown on their associated selectable region. Together the ten selectable region circumscribe region (6550) on the

display. In response to only an intersection of a location indicated by a movement related signal and selectable region (6506), the display changes to that shown in Figure 25, on which are located ten selectable regions each located on the display (2112) adjacent the edge of the display, nine of the ten selectable regions associated respectively with a submenu option. Selectable region (6608) is not associated with a submenu option. Any submenu option may be selected by a selection event.

Figures 26 and 27 illustrate an apparatus in accordance with still another embodiment of the Perimeter Menu aspect of the invention. Figure 26 depicts a front view of the apparatus; Figure 27 a cut away view from the top of the apparatus. Figure 26 depicts detector area (0348 in Figure 27) on, in or below which are located a plurality of selectable regions (0304), (0306), (0308), (0310), (0312), (0314), (0316), (0318), (0320), (0322), (0324), (0326), (0328), (0330), (0332), (0334), (0336), (0338), (0340) and (0342). Adjacent the detector area (0348 in Figure 27) is a berm (0350 in both Figure 26 and 27) for confining a body member of the operator or a pointer controlled by the operator to the detector area (0348 in Figure 27).

Still another apparatus in accordance with the Perimeter Menu aspect of the invention is illustrated in Figure 28 which depicts a headrest for an operator using his head to indicate a location on a display. Figure 28 shows an irregularity (0703) on the surface (0701) of the headrest. The irregularity is in physical contact with the operator and tactilely indicates to him the position of his head. The tactile indication means may be concave, convex or both or may differ from the surface in temperature. For individuals having impaired ability to sense the position of a body member, e.g. the operator's head, the tactile input thus provided to the operator improves the operator's ability to sense the position of his head.

The prototype of the invention will now be described in detail and where the preferred mode of practicing the invention differs from the prototype, the preferred mode is described. The description is broken into several parts:

1. A brief overview of how a state table works.
2. A description of the operation of the events, state table and state processing used in the prototype.
3. A general description of each event and one example of the use of that event.
4. An example of state machine processing in the operation of the prototype.

The prototype implements the Perimeter Menu aspect of the invention as a state table. A state table is a tool for processing sequential inputs and is most easily understood by analogy. Imagine yourself in a room having a ticket window and three exits, each regulated by a turnstile. You collect a ticket at the ticket window which, when inserted into the appropriate turnstile, allows passage to a connecting room. The turnstile keeps the ticket. Any given ticket operates only one turnstile in a room, though different tickets may operate the same turnstile. You begin in a certain room, collect a ticket, insert it into the appropriate turnstile and pass to a connecting room, where you perform certain tasks associated with the new room. Then you collect another ticket from the ticket window in that room, insert the ticket into the appropriate turnstile in that room, pass to a connecting room, perform certain tasks associated with the new room, and so on.

The state table used in the prototype is depicted in Figures 29 and 30. Moving from the analogy above, the rooms are states represented by the rows of the state table; the tickets are events represented by the columns of the state table. Each entry in the state table represents a passage from one state to another. The tasks performed upon entry into a room correspond to the processing performed by the processor (2104) on entry to a new state ("state processing"). For example, state processing may cause a slight lightening of the color of a selectable region. Reentry into that state five times may successively lighten a selectable region five times.

In the prototype, each selectable region is directly controlled by one associated state machine. Each state machine directly controls only its associated selectable region. Each state machine includes data uniquely associated with its associated selectable region, the shared state table shown in Figures 29 and 30, and the shared code for state processing, described below. This embodiment means that the state machine associated with selectable region (1614) may be in state ST_SELECTED while the state machine associated with selectable region (1602) is in state ST_INITIAL. In the prototype, these separate states are reflected only in separate values for data uniquely associated with each state machine. Each state machine has a unique index.

The state table used in the prototype defines 18 states, composed of states zero through seventeen shown in Figures 29 and 30. State 1 (ST_ERROR_STATE in Figure 29) is not used. Preferably, it is omitted. In the prototype, the differences between the several state machines, for example, the state of a particular state machine at any given time, are confined to data structures associated with that state machine. The state machines share the same code and the same state table. In other words, returning to the ticket and turnstile analogy, there are multiple travelers each with his own

ticket (event) and his own baggage (data) moving from room to room in the same labyrinth. Each traveler's actions in each room usually affect only his own baggage.

In the prototype, there are two types of sequential inputs processed by the state table: external events and internal events. External events are generated outside the state table, for example, by the operator moving the pointer (2202) or by a timer expiring. Pointer movement may generate an event indicating that the operator has moved the cursor across the selectable region boundary from without the selectable region to within it. This event causes a transition from one state to another ("drives" a state machine to a new state). For example, assuming a state machine is in state ST_CREST_TIDE, row 6 in the state table shown in Figure 29, when an event EV_CROSS_OUT, column 4 of the state table, occurs. At the intersection of row 6 and column 4 is a 7. This represents the new state, row 7 of the state table, state ST_SELECTED. Thus event EV_CROSS_OUT drives the state machine from state ST_CREST_TIDE to state ST_SELECTED. On entry to the new state, the computer performs the state processing associated with the new state.

Internal events are generated during state processing to handle circumstances where a first state transition is made due to an external event and the processing associated with the new state determines that a second state transition is necessary. The first, external, event has already been used so a second, internal, event is generated by the state. For example, if the operator has a prolonged muscle spasm, common among individuals with CP, or loses his grip on a hand held pointing device, the cursor may sit without moving on a selectable region for a considerable period of time. It is desirable to detect this condition, move the cursor to the center of the screen so the operator can easily find the cursor, and reset all selectable regions to their initial color. Detection is accomplished with a timer. On timer expiration, a state machine transitions to state ST_IDLE which centers the cursor. From there it is desirable to transition to state ST_RESET which, among other processing, initializes selectable region color. The transition from state ST_IDLE to state ST_RESET is driven by an internal event, generated by state ST_IDLE state processing.

Although the preferred embodiment uses only one state to perform certain state processing, that state processing may be equivalently performed in multiple states. Likewise, the state processing of multiple states of the described embodiment may be equivalently performed in a single state.

Although the prototype uses a state table to control the flow of program execution and to select one of a plurality of selectable regions, the same function may be equivalently performed using object

oriented software architecture, if-then-else statements or a combination of these. In particular, in accord with object oriented software architecture, each state machine may be equivalently represented as an instantiation of a selectable region class for processing inputs affecting a particular selectable region.

Although the described embodiment uses a single processor, state table and code for state processing for all the selectable regions, each of these may be duplicated. Alternate embodiments may include processors, electronic circuitry, state tables or code for state processing used for processing fewer than all the selectable regions or used to process certain selectable regions at one time and other selectable regions at other times.

In the prototype, each state machine processes events independently of all other state machines, though a state machine may send an event to another state machine. For example, when the operator selects a selectable region, the associated state machine sends the event EV_RESET to all other state machines so that all selectable regions revert to their respective initial colors.

A single operator action may result in the issuance of different events to different state machines. For example, when the operator moves the cursor from without a selectable region to within it, EV_DWELL is sent to the newly indicated state machine. EV_MOVEMENT is sent to all other state machines.

Following is a general description of each event used in the prototype and an example of the use of each event. For all uses of each event, refer to the state table shown in Figures 29 and 30 which determines what state transition occurs from every state on occurrence of a given event.

The event EV_RESET is an internal event which drives a state machine to its initial state. For example, when the operator has not moved the pointer (2202) for a predetermined period of time, event EV_RESET is sent to all other selectable regions.

The event EV_DECAY is an external event which indicates that the cursor hotspot does not intersect the selectable region associated with the state machine. EV_DECAY is sent to a state machine periodically when the operator has positioned the cursor hotspot on a selectable region other than the selectable region associated with that state machine.

The event EV_DWELL is an external event which indicates that the cursor hotspot intersects the selectable region associated with the state machine. EV_DWELL is sent to a state machine periodically when the operator has positioned the cursor hotspot on the associated selectable region.

The event EV_CROSS_OUT is an external event which indicates that the cursor hotspot has moved from a location intersecting the selectable region associated with the state machine to a location not intersecting the selectable region. After the operator selects a selectable region, he must move the cursor hotspot out of the selectable region, generating EV_CROSS_OUT, before he can again select that selectable region.

The event EV_STEP_UP is an internal event which indicates that a selectable region's selection threshold has been satisfied.

The event EV_MOVEMENT is an external event which indicates that the cursor hotspot has moved. If the cursor hotspot intersects a selectable region without moving for a predetermined period of time, a timeout occurs, causing all state machines to transition to the reset state. EV_MOVEMENT drives the state machine out of the reset state.

The event EV_IDLE_TIMEOUT is an external event which indicates that the cursor hotspot has intersected a selectable region without moving for a predetermined period of time. EV_IDLE_TIMEOUT causes the state machine to move the cursor hotspot to the center of the display.

The event EV_CEILING is an external event which indicates that the cursor hotspot intersects a selectable region and the color of the selectable region equals the selectable region color ceiling. If the locking feature is enabled, EV_CEILING drives the state machine to the begin lock state where it displays the lock icon.

The null event, EV_NULL, is a multi-purpose internal event used in a variety of situations to drive a state machine to another state. For example, after a timeout has been detected, EV_IDLE_TIMEOUT is generated and sent to the appropriate state machine driving it to the idle state, the receiving state machine sends itself EV_NULL in order to drive itself to the reset state. The use of EV_NULL here allows states to be simpler and the reset state to be reused.

The prototype uses eight partially delimited selectable regions. In the description below, the portion of each selectable region shown on the display is referred to as the visible subregion of the selectable region. The portion of each selectable region outside the display is referred to as the invisible subregion of the selectable region. Because the software driver (1202) confines the cursor hotspot to the Windows® cursor clipping rectangle, a rectangle on the display slightly smaller in area than the display, the access program (1206) of the prototype only reads hotspot cursor locations within the Windows® cursor clipping rectangle, even though the operator may in fact be pointing to a location outside the Windows® cursor clipping rectangle, e.g. within an invisible subregion. Thus the access program (1206) does not distinguish between two locations indicated by the operator, the first at a first location on the edge of the Windows® cursor clipping rectangle and the second outside the Windows® cursor clipping rectangle whose location is reported by the software driver (1202) to be the first location. For example, assuming that the operator moves the location indicated by the pointer (2202) to a location within invisible subregion (0104 in Figure 17), the software driver (1202) in the prototype reports the cursor hotspot location to be the closest point within the visible subregion (0106). Consequently, in the prototype, all invisible subregions are unbounded on their side furthest from and parallel to the edge of the display. Thus, in the prototype, point (0162) in Figure 17 lies within selectable region (0128/0130) since the rightmost side of selectable region (0128/0130) is unbounded.

The operation of the prototype will now be described using, as an example, the selection of a menu option associated with selectable region (0104/0106). First described are notation conventions used in the description, then initialization in the prototype, and then the example. The description refers to the procedures PocketFsm and CreateEvent. These procedures are listed in pseudo-code in Appendix I.

Notational conventions used in the description below:

1. pPocket-> indicates a set of data associated with a particular state machine, in this example, the state machine associated with selectable region (0104/0106).
2. pPocket->State indicates a particular item of data within the set of data associated with the state machine, in this case, the variable "State".

During initialization:

1. The Windows® cursor clipping rectangle is set so that most of the arrow cursor is always visible on the display.

2. The cursor, indicating on the display (2112) the location indicated by the movement related signal receiving means, is positioned at the center of the display.
3. All data associated with each state machine are initialized. The following variables are included in the set of data associated with each state machine. There are as many independent copies of these variables as there are state machines. For each state machine the following variables are initialized as indicated.

variable	initial value	meaning
fInvert	FALSE	if TRUE, display the color complementary to that indicated by this selectable region's Color variable
State	ST_INITIAL	state of the state machine
PreviousState	0	previous state of the state machine
Color	0	RGB encoding of visible subregion color
fPaint	FALSE	if TRUE, paint visible subregion on receipt of WM_PAINT message
InitialColor	RGB (0,32,0)	initial value corresponds to a dark green
pLabel	initial menu option for the state machine's selectable region	indicates an element within the aLabel array, described below
Decrement	RGB (0,1,0)	value subtracted from Color on EV_DECAY
Increment	RGB (0,4,0)	value added to Color on EV_DWELL
Ceiling	RGB (0,255,0)	initial value corresponds to a very light, bright green
CrestTide	RGB (0,143,0)	initial value corresponds to a light green
Lockspot.x	a point within the selectable region located two thirds of the length of the selectable region from the closest corner of the display	x coordinate of location for the display of the lock icon
Lockspot.y	a point within the selectable region	y coordinate of location for the display of the lock icon

	located two thirds of the length of the selectable region from the closest corner of the display	
fInterior	TRUE for interior regions, otherwise FALSE; used for the Intersection aspect of the invention	if TRUE, this is an interior region of adjacent regions
iAdjacentPocket	index of state machine associated with the adjacent region; used for the Intersection aspect of the invention	
first array of points	boundaries of the visible subregion	
second array of points	boundaries of the region; used for the Intersection aspect of the invention	
hRegion	handle to Windows® region corresponding to the visible subregion; used for the Intersection aspect of the invention	

4. aLabel, an array of data structures defining the menu and submenu options and the menu hierarchy, is initialized. For example, one of the elements of aLabel defines menu option "vort<space>x". This element includes fields which determine that this menu option is displayed horizontally starting at certain (x,y) coordinates, that on selection certain actions are to be taken, for example, outputting text to a speech synthesizer, and that on selection certain submenu options, in this example, "v", "o", "r", "t", "<space>" and "x", and related data are to be associated with certain state machines. In the prototype, this association is

accomplished by modifying pLabel in the set of data of the associated state machine to point to the aLabel element corresponding to the menu option to be associated with that state machine.

5. At least one window is created in the circumscribed region (0150) for the display of selected letters.

6. The state table is initialized to the values shown in Figures 29 and 30.

7. EV_RESET is sent to each state machine by a procedure call of the form PocketFsm (pPocket, EV_RESET). As an example, assume pPocket indicates the state machine associated with selectable region (0104/0106). Proceeding through the pseudo-code for the procedure PocketFsm listed in Appendix I, fInternalEvent is set to TRUE and consequently control passes into the while loop. fInternalEvent is now set to FALSE. The current state, pPocket->State, is stored in pPocket->PreviousState. Now a state transition is made. The current state, ST_INITIAL, having a value of 2, and the current event, EV_RESET, having a value of 1, are used as row and column indices respectively into the state table aPocketFsm shown in Figures 29 and 30, to determine the value of the new state of the state machine, in this example, the state machine associated with selectable region (0104/0106). aPocketFsm[2][1] equals 3. Thus the new state of the state machine is 3, the value of ST_RESET. Control passes, via the switch statement, to the ST_RESET case and ST_RESET state processing is performed. The time of selectable region selection is set to the current time, the state machine's fInvert flag is set to FALSE and the value of the state machine's color variable, pPocket->Color, is compared to the state machine's initial color, pPocket->InitialColor. pPocket->Color was initialized to zero, which is not the value of pPocket->InitialColor. Consequently, pPocket->Color is set to pPocket->InitialColor and the flag pPocket->fPaint is set to TRUE. Upon reaching the break statement, control passes through the bottom of the switch statement and the value of pPocket->fPaint is tested. Since it is TRUE, the client area rectangle is invalidated. In the prototype, Windows® (1204) responds to invalidating the client rectangle by sending the access program (1206) a WM_PAINT message. On receipt of a WM_PAINT message, the access program (1206) redraws all selectable regions and any menu option located thereon for each state machines having pPocket->fPaint equal to TRUE. Thus, somewhat indirectly, visible subregion (0106) is drawn on the display (2112). Then control returns to Windows® (1204). The other seven state machines, each associated respectively with a selectable region, are similarly initialized so that each state machine transitions from ST_INITIAL to ST_RESET and draws its respective visible subregion and any menu option located thereon on the display (2112). The

display shown in Figure 17 now appears on the display (2112) of the computer system (2116).

8. A periodic timer, called the cursor polling timer, is set. This timer provides the access program (1206) with a WM_TIMER message at frequent intervals, in the prototype every system clock tick which occurs approximately every 54 milliseconds. Following access program (1206) initialization, most state transitions are made on expiration of the cursor polling timer. The access program (1206) calls the procedure CreateEvent to determine the appropriate event for each state machine and to complete the event data structure addressed by pEvent accordingly, then repetitively calls the procedure PocketFsm for each state machine, passing the unique indicator for the state machine and the appropriate event for that state machine. Preferably, the cursor polling timer is more frequent so that color changes to visible subregions are smaller and more frequent, giving a smoother appearance to color change.

An example of the selection of selectable region (0104/0106) in accord with the Perimeter Menu aspect of the invention will now be described. Following initialization, assume that the operator now begins to move the pointer (2202). Every 54 milliseconds the cursor polling timer expires, causing Windows® (1204) to send a WM_TIMER message to the access program (1206). Following receipt of WM_TIMER, the access program (1206) calls the procedure CreateEvent. The procedure CreateEvent, among other functions, determines whether the current cursor hotspot location lies within any selectable region. In this example, the operator is moving the cursor from its initial location in the center of the display toward selectable region (0104/0106), but since only 54 milliseconds have elapsed, the cursor hotspot has moved only slightly in that direction. The procedure CreateEvent determines that the cursor hotspot does not lie within any selectable region and that the cursor hotspot has not crossed out of a selectable region in the past 54 milliseconds. Therefore, the procedure CreateEvent determines that each state machine should receive EV_MOVEMENT. The procedure PocketFsm is called with the indicator for the state machine associated with selectable region (0104/0106) and with EV_MOVEMENT. The event EV_MOVEMENT drives this state machine from its current state, ST_RESET, to ST_EBB_TIDE. The pseudo-code for ST_EBB_TIDE in procedure PocketFsm is a break statement, indicating that no state specific action is taken at this time, other than the transition to ST_EBB_TIDE. Control returns to Windows® (1204).

Shortly before or shortly after the state machine associated with selectable region (0104/0106)

receives EV_MOVEMENT, all other state machines each receive EV_MOVEMENT and each makes the same transition from ST_RESET to ST_EBB_TIDE.

Another 54 milliseconds elapses and again procedure PocketFsm is called, sending EV_MOVEMENT to the state machine associated with selectable region (0104/0106) and driving state machine from ST_EBB_TIDE to ST_DECAY. Stepping through the pseudo-code for ST_DECAY, the ST_DECAY state sets pPocket->State to the value stored in pPocket->PreviousState and decrements pPocket->Color but not below the value of pPocket->InitialColor. pPocket->Color determines the color and brightness of visible subregion (0106). Decrementing pPocket->Color results in a darkening of visible subregion (0106). Resuming with the pseudo-code for ST_DECAY state processing, the ST_DECAY state sets fInternalEvent to TRUE, and, in this case, sets Event to EV_NULL. Following the break statement, the while fInternalEvent condition is true and another state transition occurs, using the value of pPocket->State which was set by ST_DECAY state processing to ST_EBB_TIDE, the previous state. The new state is found at aPocketFsm[ST_EBB_TIDE][EV_NULL], which equals ST_EBB_TIDE. This state transition is unlike an ordinary state transition because the starting state is set by ST_DECAY. All transitions from ST_DECAY share this distinction. The state machine executes the code for the new state, ST_EBB_TIDE, which is simply a break statement. The procedure PocketFsm determines that fPaint is FALSE and exits. Control returns to Windows® (1204).

Shortly before or shortly after the state machine associated with selectable region (0104/0106) receives EV_MOVEMENT, all other state machines each receive EV_MOVEMENT and each makes the same transitions from ST_EBB_TIDE to ST_DECAY to ST_EBB_TIDE.

Every 54 milliseconds this scenario is repeated for each state machine until the operator moves the cursor hotspot to a point within selectable region (0104/0106). At this time the procedure CreateEvent determines that there is an active selectable region, specifically selectable region (0104/0106), and that consequently EV_DWELL should be sent to the associated state machine. The procedure PocketFsm is called with the indicator for the state machine associated with selectable region (0104/0106) and the event EV_DWELL. EV_DWELL drives this state machine from ST_EBB_TIDE to ST_ENTRY. Following the pseudo-code for ST_ENTRY state processing shown in PocketFsm pseudo-code, fInternalEvent is set to TRUE and Event is set to EV_NULL, resulting in another state transition to aPocketFsm[ST_ENTRY][EV_NULL], which equals

ST_LOW_TIDE.

The pseudo-code for ST_LOW_TIDE is only a break statement, so there is no state specific action for ST_LOW_TIDE other than entry into this state. fPaint is FALSE so the selectable region is not redrawn. Control returns to Windows® (1204).

Shortly before or shortly after the state machine associated with selectable region (0104/0106) receives EV_DWELL, all other state machines each receive EV_MOVEMENT and each makes the same transitions from ST_EBB_TIDE to ST_DECAY to ST_EBB_TIDE.

Another 54 milliseconds elapses. The procedure CreateEvent determines that the state machine associated with selectable region (0104/0106) should receive EV_MOVEMENT, which drives it from ST_LOW_TIDE to ST_DWELL. Stepping through the pseudo-code for ST_DWELL, the ST_DWELL state sets pPocket->State to the value stored in pPocket->PreviousState, increments pPocket->Color by pPocket->Increment, but not above the value of pPocket->Ceiling, sets pPocket->fPaint to TRUE, sets fInternalEvent to TRUE, and, in this case, sets Event to EV_NULL. Following the break statement, the while fInternalEvent condition is true and another state transition occurs. The new state is found at aPocketFsm[ST_LOW_TIDE][EV_NULL], which equals ST_LOW_TIDE. This path is unlike an ordinary state transition because the starting state is set by ST_DWELL. All transitions from ST_DWELL share this distinction. The state machine executes the code for the new state, ST_LOW_TIDE, which is simply a break statement. The procedure PocketFsm determines that fPaint is TRUE, invalidates the client rectangle and exits. As a result of invalidating the client rectangle, Windows® (1204) sends a WM_PAINT message to the access program (1206). On receipt of WM_PAINT, the access program (1204) checks the value of fPaint for each state machine, and if TRUE, sets fPaint to FALSE and redraws the visible subregion of the selectable region associated with that state machine and any menu option located thereon. The color of the redrawn visible subregion is determined by the value of the Color variable for that state machine. After redrawing, control returns to Windows® (1204).

Shortly before or shortly after the state machine associated with selectable region (0104/0106) receives EV_DWELL, all other state machines each receive EV_MOVEMENT and each makes the state transitions from ST_EBB_TIDE to ST_DECAY to ST_EBB_TIDE.

Assuming the operator maintains the cursor hotspot in the selectable region (0104/0106), the state

machine associated with selectable region (0104/0106) cycles repetitively through the state transitions from ST_LOW_TIDE to ST_DWELL to ST_LOW_TIDE, driven by the cursor polling timer. With each transition to ST_DWELL, visible subregion (0106) is brightened a bit. The polling timer interval is short enough and the increment to pPocket->Color is small enough that visible subregion (0106) appears to gradually brighten although in fact it progresses rapidly through a series of discrete brightness levels. With each iteration through ST_DWELL, pPocket->Color in incremented.

Assuming that the operator maintains the cursor hotspot on selectable region (0104/0106), pPocket->Color will eventually equal or exceed pPocket->CrestTide, a variable set at initialization time and not changed thereafter. At this time, Event is set to EV_STEP_UP, driving a transition to aPocketFsm[ST_LOW_TIDE][EV_STEP_UP], which equals ST_SELECTED. The state processing for ST_SELECTED provides the operator with an audible indication that a selection has just been made, takes the action appropriate upon selection of this selectable region, including selecting the menu option associated with the selected selectable region. In this example, the access program (1206) does not generate output to another program or device at this time. ST_SELECTED next sets pPocket->fInvert to TRUE, and, if appropriate, changes the menu options associated with various selectable regions. In this example, selectable region (0104/0106) is now associated with menu option "<space>", selectable region (0108/0110) with menu option "o", selectable region (0112/0114) with menu option "t", selectable region (0124/0126) with menu option "x", selectable region (0128/0130) with menu option "v", and selectable region (0132/0134) with menu option "r". Selectable regions (0116/0118) and (0120/0122) remains associated with the same menu options with which they were associated in Figure 17. fPaint is set to TRUE for the state machines associated with the selectable regions having changed menu options. ST_SELECTED next sets Event to EV_NULL and fInternalEvent to TRUE. The state machine now makes the transition to aPocketFsm[ST_SELECTED_TIDE][EV_NULL], which equals ST_CREST_TIDE. There is no state specific action for ST_CREST_TIDE other than entry into this state. The pseudo-code for ST_CREST_TIDE is only a break statement. Control returns to Windows® (1204).

When the access program (1206) later receives the WM_PAINT message resulting from the invalidating of the client rectangle, the setting of fInvert to TRUE causes the visible subregion (0106) to be drawn in the color complementary to the value then indicated by pPocket->Color. The setting of fPaint to TRUE for all selectable regions associated with changed menu options

causes those selectable regions and the menu options thereon to be redrawn. The display shown in Figure 18 now appears on the display (2112) of the computer system (2116).

Assuming the operator maintains the cursor hotspot in the selectable region (0104/0106), the state machine associated with selectable region (0104/0106) cycles repetitively through the state transitions from ST_CREST_TIDE to ST_DWELL to ST_CREST_TIDE, driven by the cursor polling timer. With each transition to ST_DWELL, visible subregion (0106) is brightened a bit, though it is now magenta, the complement of green. The polling timer interval is short enough and the increment to pPocket->Color is small enough that visible subregion (0106) appears to gradually brighten although in fact it progresses rapidly through a series of discrete brightness levels. With each iteration through ST_DWELL, pPocket->Color in incremented. Assuming that the operator maintains the cursor hotspot on selectable region (0104/0106), pPocket->Color will eventually equal pPocket->Ceiling, a variable set at initialization time and not changed thereafter.

Assuming that the operator now moves the cursor so that the hotspot is located outside selectable region (0104/0106), CreateEvent generates the EV_CROSS_OUT for the state machine associated with selectable region (0104/0106), driving the state machine to aPocketFsm[ST_CREST_TIDE][EV_CROSS_OUT], which equals ST_SELECT_AND_OUT. The state processing for ST_SELECT_AND_OUT sends EV_RESET and then EV_MOVEMENT to all state machines, driving each of them from their current state to ST_RESET and then to ST_EBB_TIDE. For each state machine, the transition ST_RESET and then to ST_EBB_TIDE results in actions previously described for those states, except that, unlike before, the value of pPocket->Color for the state machine associated with selectable region (0104/0106) does not equal the value of pPocket->InitialColor for the state machine associated with selectable region (0104/0106). Consequently, pPocket->Color is set to pPocket->InitialColor and fPaint is set to TRUE, subsequently causing visible subregion (0106) to be redrawn in its initial color. Control returns to Windows® (1204).

The prototype continues to sample cursor location at 54 millisecond intervals, determine the appropriate event for each state machine and send that event each state machine, causing state transitions in each state machine according to the state table shown in Figures 29 and 30. Assuming that the operator next selects selectable region (0108/0110), the state processing in ST_SELECTED displays the selection, the letter "o", in the circumscribed region (0150), and associates the menu options shown in Figure 17 with their respective selectable regions. The

display shown in Figure 17 appears on the display (2112) of the computer system (2116).

B. Confinement

The preferred embodiment of the Confinement aspect of the invention will now be described in detail from a functional perspective using an example illustrated in Figure 31. In Figure 31, 20 selectable regions, e.g. (1704), (1708) and (1714), are depicted on display (2112). Each of the selectable regions is located on the display (2112) adjacent an edge of the display, and the selectable regions together circumscribe a region (1702) on the display. The top and left edges of the Windows® cursor clipping rectangle (1750) lie on the top and left edges, respectively, of the display (2112). The bottom and right edges of the Windows® cursor clipping rectangle (1750) lie on the display parallel to and slightly indented from the bottom and right edges, respectively, of the display. A confining polygon is delimited on the display. The boundary of the confining polygon, starting from the upper right corner of the Windows® cursor clipping rectangle, follows the top edge of the Windows® cursor clipping rectangle to the left until it reaches region (1732), where the boundary follows the side of region (1732) down, to the left, and back up to the top edge of the Windows® cursor clipping rectangle. The boundary continues left along the top edge of the Windows® cursor clipping rectangle until it reaches region (1734), where the boundary follows the side of region (1734) down, to the left, and back up to the top edge of the Windows® cursor clipping rectangle. The boundary continues left along the top edge of the Windows® cursor clipping rectangle to the upper left corner and then turns down along the left edge of the Windows® cursor clipping rectangle until it reaches region (1736), where the boundary follows the side of region (1736) to the right, down, and to the left to the left edge of the Windows® cursor clipping rectangle. The boundary of the confining polygon continues in this fashion around to the upper right corner of the Windows® cursor clipping rectangle. The confining polygon thus includes all the area of the Windows® cursor clipping rectangle except for the regions (1732), (1734), (1736), (1738), (1740), (1742), (1744), and (1746). An operator controlling a pointer indicating successive locations with respect to the display and attempting to select a target selectable region may overshoot the target so that some of the successive locations lie outside the Windows® cursor clipping rectangle. In the preferred embodiment of the Confinement aspect of the invention, the cursor (1724) is confined to the confining polygon. The preferred embodiment is responsive to an intersection of the cursor hotspot and any one selectable region so that an overshot selectable region may be selected by click or by dwell without moving the location presently indicated by the pointer to a location in the overshot selectable region. Thus, the preferred

embodiment of the Confinement aspect of the invention allows an operator with impaired ability to stop motion to maintain the cursor more easily on a selectable region, and so select the intended selectable region, than do conventional user interface systems.

A selectable region having a single side abutting a confining polygon prevents cursor movement only beyond the abutting side. However. NMD operators who drift may drift in more than one direction. Assume that a certain NMD operator tends to drift both up and to the left and that he is attempting to select selectable region (1704). If he moves the cursor into that selectable region his upward drift will be confined: the drift will not move the cursor beyond the confining polygon. However. the cursor will move to the left, since, in the preferred embodiment of the Confinement aspect of the invention, movement in this direction is not affected by the confining polygon, and consequently the cursor may move into selectable region (1708), the selectable region to the left of selectable region (1704). NMD operators having this type of drift may be assisted in selecting by confining corners. For example. such an operator, attempting to select selectable region (1704) could move the cursor to location (1706) in selectable region (1704). As the operator drifts to the left, he can compensate by moving the pointer to the right. Assuming the operator lacks fine motor control. he may overcompensate and indicate a location to the right of the Windows® cursor clipping rectangle (1750). However, since the cursor is confined to the confining polygon, the cursor remains in the intended selectable region.

Confining corners facilitate the selection process for some NMD operators. The preferred embodiment of the Confinement aspect of the invention creates a corner or virtual corner in each selectable region. A virtual corner is a corner of a selectable region formed by the intersection of two sides of a selectable region both of which abut a confining polygon. For example. corner (1710) in selectable region (1708) abuts the confining polygon both along the top edge of the Windows® cursor clipping rectangle and along the right side of region (1732). If an NMD operator drifts from selectable region (1708) to the left into region (1732), the cursor remains in selectable region (1708). Thus, drift to the left does not move the cursor out of selectable region (1732). An operator trying to select selectable region (1708) may overcompensate for drift to the right by moving the pointer to indicate a location in region (1732).

Figure 32 illustrates a display in accordance with an alternative embodiment of the Confinement aspect of the invention. Figure 32 depicts 16 selectable regions. e.g. selectable region (0602), on a display (2112). the selectable regions together at least partially circumscribing region (0660) on the

display. Circumscribed region (0660) intersects four selectable regions, (0604), (0608), (0610), and (0612). Selectable region (0608) includes virtual corner (0652). The confining polygon includes all the area of the Windows® cursor clipping rectangle except for regions (0632), (0634), (0636), (0638), (0640), (0642), (0644), and (0646).

Figure 33 illustrates a display and structures in accordance with an another embodiment of the Confinement aspect of the invention. Figure 33 depicts 20 selectable regions, e.g. selectable region (0918), on a display (2112), the selectable regions together at least partially circumscribing region (0902) on the display. The confining polygon includes all the area of the Windows® cursor clipping rectangle except for regions (0906), (0908), (0910), and (0904).

The preferred embodiment of the Confinement aspect of the invention will now be described in detail from an implementation perspective. Preferably, the Confinement aspect is implemented by modifications to the access program (1206) described in the detailed description of the Perimeter Menu aspect of the invention. The modifications required are: (1) define 20 state machines and 20 respectively associated selectable regions located as shown in Figure 31; (2) at initialization time, create a Windows® region corresponding to the confining polygon described above in the functional description of the preferred embodiment of the Confinement aspect of the invention; and (3) modify the procedure CreateEvent so that before generating an EV_CROSS_OUT event, CreateEvent determines whether the current hotspot cursor location intersects the confining polygon, and, if not, set the Windows® hotspot cursor location to the previous hotspot cursor location and transfers control to the code at the beginning of the CreateEvent procedure which gets the current cursor hotspot location from Windows®. If the current hotspot cursor location intersects the confining polygon, CreateEvent takes the same action as in the access program (1206).

C. Dwell

The preferred embodiment of the Dwell aspect of the invention will now be described in detail from a functional and implementation perspective. The prototype implements dynamic dwell. The effect of dwelling on a selectable region and its implementation have been described in the detailed description of the Perimeter Menu aspect of the invention. Now the effect and implementation of moving the cursor hotspot off a selectable region will be described.

Referring now to Figure 17, assuming that the state machine associated with the selectable region (0104/0106) is in state ST_LOW_TIDE, that pPocket->Color has been incremented above its initial value, that the cursor hotspot intersected selectable region (0104/0106) at the last expiration of the cursor polling timer, and that the operator initiates movement of the cursor hotspot to the right from selectable region (0104/0106) toward selectable region (0132/0134) so that, when the cursor polling timer next expires, the cursor hotspot is located in area (0150) between visible subregions (0106) and (0134), the procedure CreateEvent determines that the state machine associated with selectable region (0104/0106) should receive EV_CROSS_OUT, which drives it from ST_LOW_TIDE to ST_LOW_TIDE. The state processing for ST_LOW_TIDE has already been described in the detailed description of the Perimeter Menu aspect of the invention.

Assuming that the operator continues to move the cursor hotspot toward selectable region (0132/0134), on the next expiration of the cursor polling timer, the procedure CreateEvent determines that the state machine associated with selectable region (0104/0106) should receive EV_MOVEMENT, which drives it from ST_LOW_TIDE to ST_DECAY. Stepping through the pseudo-code for ST_DECAY, the ST_DECAY state sets pPocket->State to the value stored in pPocket->PreviousState, decrements pPocket->Color by pPocket->Decrement, but not below the value of pPocket->InitialColor, sets pPocket->fPaint to TRUE, sets fInternalEvent to TRUE, and, in this case, sets Event to EV_NULL. Following the break statement, the while fInternalEvent condition is true and another state transition occurs. The new state is found at aPocketFsm[ST_LOW_TIDE][EV_NULL], which equals ST_LOW_TIDE. This path is unlike an ordinary state transition because the starting state is set by ST_DECAY. All transitions from ST_DECAY share this distinction. The state machine executes the code for the new state, ST_LOW_TIDE, which is simply a break statement. The procedure PocketFsm determines that fPaint is TRUE, invalidates the client rectangle and exits. As a result of invalidating the client rectangle, Windows® (1204) sends a WM_PAINT message to the access program (1206). On receipt of WM_PAINT, the access program (1204) checks the value of fPaint for each state machine, and if TRUE, sets fPaint to FALSE and redraws the visible subregion of the selectable region associated with that state machine and any menu option located thereon. The color of the redrawn visible subregion is determined by the value of the Color variable for that state machine. After redrawing, control returns to Windows® (1204).

If the movement of the cursor hotspot pause between successive samplings of its location, the procedure Create Event will determine that not EV_MOVEMENT, but EV_DECAY, should be

sent to the state machine associated with selectable region (0104/0106). Like EV_DECAY, EV_MOVEMENT drives the state machine associated with selectable region (0104/0106) to ST_DECAY. The same state processing as described above for ST_DECAY takes place, including the transition back to ST_LOW_TIDE.

Assuming the operator maintains the cursor hotspot in area (0150), the state machine associated with selectable region (0104/0106) cycles repetitively through the state transitions from ST_LOW_TIDE to ST_DECAY to ST_LOW_TIDE, driven by the cursor polling timer. With each transition to ST_DECAY, visible subregion (0106) is darkened a bit. The polling timer interval is short enough and the decrement to pPocket->Color is small enough that visible subregion (0106) appears to gradually darken although in fact it progresses rapidly through a series of discrete brightness levels. With each iteration through ST_DECAY, pPocket->Color in decremented until pPocket->Color reaches pPocket->InitialColor.

When the cursor hotspot reaches selectable region (0132/0134), the procedure CreateEvent determines that the state machine associated with selectable region (0104/0106) should receive EV_DECAY, continuing the repetitively cycling through from ST_LOW_TIDE to ST_DECAY to ST_LOW_TIDE, driven by the cursor polling timer. Driven by the same polling timer, the procedure CreateEvent determines that the state machine associated with selectable region (0132/0134) should receive EV_DWELL, driving this state machine through the state transitions described in the detailed description of the Perimeter Menu aspect of the invention.

If the operator moves the cursor hotspot from selectable region (0132/0134) back to selectable region (0104/0106), the procedure CreateEvent determines that the state machine associated with selectable region (0104/0106) should receive EV_DWELL, driving this state machine through the state transitions described in the detailed description of the Perimeter Menu aspect of the invention.

In the prototype, the selectable regions are shown on a display (2112). Alternatively, the selectable regions may appear on a static display, or they may be projected on a surface.

In the prototype, the brightness of a visible subregion at any time indicates the progress of the selection of the selectable region including the visible subregion. A brightness close to the initial brightness indicates that a relatively long period of dwelling on this selectable region is required for selection. A brightness close to the brightness just prior to selection indicates that relatively

short period of dwelling on this selectable region is required for selection. However, means for indicating an intersection of the location indicated by the movement related signal and a selectable region, or the duration of a period of such an intersection includes, but is not limited to, a change in cursor appearance or location, a change in location, size, shape, hue, brightness, contrast, tone, dithering, pattern, hatching, font or fill of an object on the surface, a display of or change in a graphic on the surface or the removal of a graphic from the surface, a generation of a sound or a change in the pitch or volume of an extant sound, a change in the temperature or surface of a contact area, the pressure exerted by a contact area, or frequency of contact by a contact area, or other suitable means. Any of these indications may be continuous or frequent.

Although dwell is implemented in the prototype using a data value, specifically pPocket->Color, it may be implemented using a signal, for example, voltage or current, varying in response to the intersection and subsequent non-intersection of a location indicated by a pointer and a selectable region. For example, a selectable region may include a detector and coupled electronics or electrical circuitry operative to increase the voltage level of a capacitor. Once elevated, the voltage level may decrease over time. Upon reaching a predetermined threshold, the voltage level may trigger selection.

The prototype allows an operator to make selections by dwell more efficiently than in conventional systems. In the prototype, the brightness of a visible subregion indicates the dwell time required for selection. A practiced operator may accurately estimate when he may plan his next pointer movement, when he may begin moving the pointer and may determine when a bit more exertion will select a selectable region and when it will not. Thus a disabled operator who is fatigued by computer access and can maintain a pointer in a steady position for only brief periods, may optimize his energy expenditure, for example, exerting himself to maintain the cursor on a certain selectable region only when doing so will quickly select the selectable region.

The prototype may increase the independence of a disable individual by allowing him to control devices such as a TV, thermostat and other household appliances. As stated earlier, the Perimeter Menu aspect of the invention may be implemented on a general purpose computer system. If the general purpose computer system is coupled to a devices capable of executing commands and the menu hierarchy allows the selection of commands, a disabled operator may select and issue commands to control these devices.

Figure 34 illustrates a display in accordance with of an embodiment of the Dwell aspect of the invention having 20 selectable regions (3101), (3103), (3105), (3107), (3109), (3111), (3115), (3117), (3119), (3121), (3125), (3127), (3129), (3131), (3133), (3135), (3139), (3141), (3143), and (3145) circumscribing a surface (3151) having an indicating region (3147) thereon.

Figure 35 illustrates an apparatus in accordance with of an embodiment of the Dwell aspect of the invention having 20 selectable regions circumscribing a surface, each selectable region associated respectively with an indicating region adjacent its associated selectable region. Selectable region (3101) is associated with indicating region (3201), selectable region (3103) with indicating region (3203), etc.

Figure 36 illustrates an apparatus in accordance with of an embodiment of the Dwell aspect of the invention having 20 detectors circumscribing an aperture (3350), each detector associated respectively with an indicator intersecting its associated detector, e.g. detector (3301) is associated with indicator (3303).

Figure 37 illustrates an apparatus in accordance with of an embodiment of the Dwell aspect of the invention having 24 selectable regions arranged in a grid of four rows and six columns, each selectable region associated respectively with an indicating region intersecting its associated selectable region. For example, selectable region (3402) is associated with indicating region (3401).

Figure 38 illustrates a display in accordance with of an embodiment of the Dwell aspect of the invention having a plurality of detectors, (2501), (2503), (2505), etc., arranged in a grid. Each detector is associated respectively with an indicator intersecting its associated detector., e.g. detector (2501) is associated with indicator (2502). Each detector is also associated respectively with an order entry item which may be selected by dwell. For example, detector (2501) is associated with a hamburger. Pointer (2512) (not drawn to scale) emits energy detectable by the detectors. Pointer (2512) may be housed in stationary housing (2514) (not drawn to scale).

Means for determining the difference between two data items or signals and means for totaling two or more data items or signals may each include a processing unit programmed to calculate this difference or total. Alternatively, the difference or total may be determined by electronic, mechanical, optical, or other suitable means.

The two step procedure described earlier for operating conventional menu-driven data entry and order entry systems incorporating pointing at intended selections may be simplified to a single step in accordance with the Dwell aspect of the invention. Referring now to Figure 38, the operator points pointer (2512) at an order entry item. The item brightens responsive to the signals falling on the associated detector, indicating to the operator which order entry item he is dwelling on and his dwell time on that order entry item. When his dwell time equals or exceeds the selection threshold, the order entry item is selected. The operation of such a system is intuitive and may be learned or relearned by pointing and dwelling. No surface is required, unlike a standard mouse. Additionally, an operator seated in the driver's seat of a vehicle is probably right-handed and may be making selections with his left hand, the hand closest to the window in a left-hand drive vehicle. Pointing and maintaining a pointer in a steady position requires less coordination than pointing and clicking.

D. Path Directness

The Path Directness aspect of the invention includes several aspects, hereinafter "subaspects", called Facilitated Dwell, Direction and Intersection, Direction, Appraisal and Drift Attenuation. The preferred embodiment and certain alternative embodiments of each of these subaspects will now be described.

According to the Facilitated Dwell subaspect of the invention, the duration of the dwell period required for selection ("selection threshold period") of a menu option associated with a selectable region varies with the directness of the cursor's path to that selectable region. The preferred embodiment of the Facilitated Dwell subaspect of the invention will now be described in detail from a functional perspective using an example illustrated in Figure 39. In Figure 39 on display (2112) are defined corridors (2302), (2304), (2306), (2308), (2310), (2312) and (2314) lying between the previously selected selectable region (2318) and, respectively, selectable regions (2342), (2344), (2346), (2348), (2350), (2352) and (2354). Each selectable region is associated respectively with a selection threshold period. Each cursor location in a cursor path, for example cursor path (2322), may slightly decrease one or more the selection threshold periods, except for the selection threshold period associated with the previously selected selectable region, selectable region (2318) in this example. The effect of a cursor location depends, in the preferred embodiment, on whether that cursor location intersects one of the corridors. If it does, as for example location (2324) intersects corridor (2308), then the selection threshold period associated with the selectable region to which the intersected corridor leads, (2348) in this example, is

decreased, preferably to a limit of approximately 20% of the initial value of the selection threshold period so that some period of intersection of the cursor and the intended selectable region is still required for selection. A changed selection threshold period is preferably indicated by a change in the brightness of the selectable region associated with the changed selection threshold period. Thus, when the operator moves the cursor within a corridor, the selectable region associated with the corridor brightens, indicating both the target selectable region the system believes the cursor is headed toward and the changed selection threshold period. When the operator moves the cursor outside a corridor the cursor had previously intersected, the selectable region associated with the previously intersected corridor darkens in accord with the dynamic dwell aspect of the invention, indicating both that the system no longer believes the cursor is headed toward that selectable region and the changed selection threshold period. Reducing the selection threshold period facilitates selection of dwell-selectable regions without unduly increasing the likelihood of erroneous selections, since cursor locations within a corridor evidence the operator's intention to select the selectable region associated with the corridor.

Preferably, corridors are hidden from view , but they may be may be shown on the display or shown only at certain times or under certain conditions. Corridors may have fixed boundaries, depending on which selectable region has been selected, or their boundaries may be determined when a starting location, for example, cursor location (2316) in Figure 39, is known. Corridor shape, size, number and position about the associated selectable region may vary, as illustrated by the alterative embodiments shown in Figures 40 and 41. Where corridors overlap, a cursor location intersecting two or more corridors may be defined to be in a cursor path toward zero, one or more selectable regions associated with the intersected corridors.

The intersection of a cursor location and a corridor is but one means of identifying which one of a plurality of selectable regions is most nearly along a cursor path. A cursor path may be indicated by an intersection of a cursor location and a predetermined region, e.g. a corridor, by a cursor location and a movement related signal from which may be derived a second location, or by two or more successive cursor locations. As used herein, successive locations include a plurality of locations distributed in time. Successive location may be, but need not be, consecutive. Given a location and a movement related signal or two locations, an intention to select a particular selectable region may be inferred, for example, by extrapolation, and the selection thresholds associated with either or both the intended or unintended selectable regions modified accordingly. As an example, assume successive cursor locations are periodically stored in a ring buffer and the

magnitude of the angle between two line segments, the first between the oldest cursor location in the ring buffer and a predetermined point in the selectable region, and the second between the oldest cursor location in the ring buffer and the current cursor location, is determined. The selectable region associated with the smallest of these angles may be considered to be the selectable region most nearly along the cursor path indicated by the first line segment.

An alternative means of identifying which one of a plurality of selectable region is most nearly along a cursor path is to determine the ratio of the number cursor locations indicating a selectable region to the total cursor locations in the cursor path.

Figure 42 illustrates still another alternative means for identifying which one of a plurality of selectable regions is most nearly along a cursor path. Figure 42 shows line (2410) from starting cursor location (2406) to ending cursor location (2408) just within selectable region (2404). Line (2410) is the most direct path between these two points. In this example, the actual path traveled by the cursor between these two points is path (2412). The ending cursor location (2408) is known before the selection threshold period associated with selectable region (2404) is modified. Identification may be made by measuring or approximating the area within region (2414) bounded by line (2410) and cursor path (2412). The smaller the area, the more direct the cursor path. Alternatively, identification may be made by storing a sampling among successive cursor locations along a cursor path and, in response to the cursor intersecting a selectable region, the selectable region most nearly along the cursor path may be identified at one or more sampled points along the cursor path. The identification may be based upon a plurality of cursor locations or upon a single cursor location and a movement related signal. Alternatively, identification may be made by measuring and comparing the number of times a cursor path diverges from a predetermined path toward the intersected selectable region and/or the degree of divergence of a cursor path from a predetermined path toward the intersected selectable region.

Another apparatus in accord with the Path Directness aspect of the invention is illustrated in Figure 34. In this Figure, selectable regions (3101), (3103), (3105), (3107), (3109), (3111), (3115), (3117), (3119), (3121), (3125), (3127), (3129), (3131), (3133), (3135), (3139), (3141), (3143) and (3145) circumscribe area (3151). Area (3151) and optionally the selectable regions include detectors for sensing radiant energy emitted from a pointer (2202) coupled to a body member of the operator. A computer coupled to the detectors determines which selectable region is most nearly along the path indicated by the body member of the operator. Responsive to the indicated path, the

embodiment may facilitate the selection of one of the selectable regions by reducing a selection threshold, may select a selectable region upon intersection of the point indicated by the pointer (2202) and a selectable region, or may select a particular selectable region in advance of intersection of the point indicated by the pointer (2202) and the particular selectable region.

A move direction of a body member of an operator may be determined in any way that a cursor path may be determined, including sampling among data indicative of position of the body member. In determining move direction of a body member, data indicative of body member positions may serve the same function as cursor locations in indicating a path toward a selectable region. Position indicating means, used, for example, in indicating a position of the body member, includes each of the means for indicating that a selection event has occurred.

As an alternative to decreasing a selection threshold period, an embodiment may include a plurality of selection thresholds, each associated respectively with a selectable region. One or more of the selection thresholds may be increased when the direction of cursor movement does not indicate a path toward the associated selectable region.

Means for indicating which one of the plurality of selectable regions is most nearly along the cursor path includes each of the means for indicating an intersection of the location indicated by the movement related signal and a selectable region.

According to the Direction and Intersection subaspect of the invention, the selection threshold period is completely satisfied in response to a cursor path to a particular selectable region, so that when the cursor intersects the particular selectable region, that region is selected. Preferably, the selection threshold period is completely satisfied in response to a measure of directness of a cursor path to a particular selectable region equalling or exceeding a predetermined measure of directness. In circumstances where the measured directness is less than the predetermined measure, a dwell period is required for selection of the particular selectable region.

According to the Direction subaspect of the invention, a selectable region is selected in response to a cursor path to that selectable region, in advance of an intersection of the cursor and that selectable region. Preferably, the selectable region is selected in response to a measure of directness of a cursor path to a particular selectable region equalling or exceeding a predetermined measure of directness. In circumstances where the measured directness is less than the predetermined

measure, a dwell period is required for selection of the particular selectable region.

According to the Appraisal subaspect of the invention, the directness of a cursor path to a selectable region is measured. Preferably, the means for measuring the directness of a cursor path includes each of the means for identifying which one of a plurality of selectable regions is most nearly along a cursor path. Thus, the particular means for identifying which one of a plurality of selectable regions is most nearly along a cursor path which best correlates with an operator's intended target selectable region may be identified.

As earlier described, some NMD operators have relatively unimpaired directional control, despite having other movement disorders. The Facilitated Dwell, Direction and Intersection, and Direction subaspects of the Path Directness aspect of the invention utilize that capability for computer access. Specifically, the ability of an operator to move a cursor in a direct path toward a selectable region is used to facilitate selection of that selectable region. The selectable region is selected more quickly than in conventional systems utilizing selection by dwell, increasing operator productivity. In addition, when selectable regions are located in accordance with the Perimeter Menu aspect of the invention, a cursor path toward a selectable region is often unambiguous, since usually there is only one selectable region along a cursor path, and a large rectangular area on the display is available for the output of an application program and is not obstructed by the menu. In certain embodiments in accordance with the Facilitated Dwell, Direction and Intersection, and Direction subaspects of the Path Directness aspect of the invention, the operator may receive an indication of which selectable region the system believes the operator is moving the cursor toward. The operator may adjust the cursor path in response to this feedback and thus move the pointer more accurately. Additionally, in embodiments in accordance with both the Facilitated Dwell subaspect of the Path Directness aspect of the invention and the Dwell aspect of the invention, the operator may receive an indication of the dwell time required to select the selectable region most nearly along the cursor path as the required dwell time changes in response to the cursor path.

The preferred embodiment of the Drift Attenuation subaspect of the invention will now be described in detail from a functional perspective using an example illustrated in Figure 43. Figure 43 depicts the upper right corner of a display (2112) having two selectable regions (0434) and (0430) thereon. Assuming, for purposes of this example, that a movement related signal indicates the path shown from point (0402) to point (0404) ("first segment") at a relatively high velocity and from point (0404) to point (0408) ("second segment") at a relatively low velocity. The path of the

first segment is relatively direct, the path of the second segment, relatively meandering. During receipt of the movement related signal for the first segment, the cursor preferably tracks the exact path indicated by the movement related signal. During receipt of the movement related signal for the second segment, the movement of the cursor is attenuated, preferably so that the cursor does not leave selectable region (0434) until it is selected.

Many NMD operators are unable to cleanly stop movement of a body member, resulting in a relatively slow or meandering path being indicated by the movement related signal. According to the Drift Attenuation subaspect of the invention, drift, that is, unintentional movement, indicated by the movement related signal following intentional movement is distinguished from the intentional movement, and cursor movement responsive to the drift is attenuated relative to cursor movement responsive to intentional movement. Thus unintentional movements of NMD operators are filtered so that the cursor is displayed closer to the location intended by the operator and drifting of the cursor into a nearby, but unintended, selectable region, is avoided, resulting in fewer errors due to unintended selections.

The preferred embodiment of each subaspect of the Path Directness aspect of the invention will now be described in detail from an implementation perspective. Preferably, the Facilitated Dwell subaspect is implemented by modifications to the access program (1206) described in the detailed description of the Perimeter Menu aspect of the invention. The modifications required are: (1) Additional state processing should be added to ST_SELECTED to create a Windows® region in the shape of a corridor starting a predetermined distance from the selected selectable region to each of the other selectable regions; (2) The event data structure should be expanded to accommodate an event for a selectable region along a cursor path; (3) The procedure CreateEvent should be changed so that, before setting an event to EV_DECAY or EV_MOVEMENT, a test is made for the intersection of the cursor hotspot and each corridor, and, on finding such an intersection, a new event, EV_CORRIDOR, is stored in the event data structure indicated by pEvent for the selectable region associated with the intersected corridor; (4) A column should be added to the state table so that each state which in the prototype may receive either EV_MOVEMENT or EV_DECAY will on receipt of EV_CORRIDOR drive that state machine to ST_CORRIDOR; (5) An additional variable, CorridorIncrement, preferably having an initial value one half the value of Increment, should be added the set of data associated with each state machine; and (6) A new state, ST_CORRIDOR, should be added to the procedure PocketFsm. The pseudo-code for state processing in ST_CORRIDOR follows:

```
case ST_CORRIDOR:
                                /* set state to previous state */
                                /* in preparation for the next */
                                /* state transition            */
        set pPocket->State to pPocket->PreviousState
        increment pPocket->Color by
        pPocket->CorridorIncrement, but not above
        pPocket->InitialColor plus 80% of the
        difference between pPocket->CrestTide and
        pPocket->InitialColor
        if pPocket->Color was changed
            set pPocket->fPaint to TRUE
        set fInternalEvent to TRUE
        set Event to EV_NULL
        break
```

An example of the selection of selectable region (2346) in accord with the preferred embodiment of the Facilitated Dwell subaspect of the invention will now be described with reference to Figure 39, assuming that the prototype has been modified as described, that the operator has just selected selectable region (2318), that all state machines are in state ST_RESET, and that the operator moves the cursor hotspot from a location inside selectable region (2318) to location (2316), a location just outside selectable region (2318). On receipt of the next WM_TIMER message, procedure PocketFsm is called with the indicator for the state machine associated with selectable region (2318) and with event EV_CROSS_OUT. Event EV_CROSS_OUT drives this state machine from its current state, ST_RESET, to ST_EBB_TIDE. The pseudo-code for ST_EBB_TIDE in procedure PocketFsm is a break statement, indicating that no state specific action is taken at this time, other than the transition to ST_EBB_TIDE. Control returns to Windows® (1204).

Shortly before or shortly after the state machine associated with selectable region (2318) receives EV_CROSS_OUT all other state machines each receive EV_MOVEMENT and each makes the transition from ST_RESET to ST_EBB_TIDE.

Assume that the operator moves the cursor hotspot along path (2322) toward location (2332), a

location outside all corridors, and then the next WM_TIMER message is received. All state machines receive EV_MOVEMENT and are driven from ST_EBB_TIDE to ST_DECAY to ST_EBB_TIDE . The state processing associated with these states has been described in the description of the Perimeter Menu aspect of the invention.

Assuming that the operator moves the cursor hotspot along path (2322), the transition from ST_EBB_TIDE to ST_DECAY to ST_EBB_TIDE is repeated every 54 milliseconds for each state machine until the operator moves the cursor hotspot beyond location (2332). At this time the procedure CreateEvent determines that the cursor hotspot intersects corridor (2308) and that consequently EV_CORRIDOR should be sent to the state machine associated with selectable region (2348). EV_CORRIDOR drives this state machine from ST_EBB_TIDE to ST_CORRIDOR. Stepping through the pseudo-code for ST_CORRIDOR, the ST_CORRIDOR state sets pPocket->State to the value stored in pPocket->PreviousState, increments pPocket->Color by pPocket->CorridorIncrement, but not above pPocket->InitialColor plus 80% of the difference between pPocket->CrestTide and pPocket->InitialColor, sets pPocket->fPaint to TRUE, sets fInternalEvent to TRUE, and sets Event to EV_NULL. Following the break statement, the while fInternalEvent condition is true and another state transition occurs. The new state is found at aPocketFsm[ST_EBB_TIDE][EV_NULL], which equals ST_EBB_TIDE. This path is unlike an ordinary state transition because the starting state is set by ST_CORRIDOR. All transitions from ST_CORRIDOR share this distinction. The state machine executes the code for the new state, ST_EBB_TIDE, which is simply a break statement. The procedure PocketFsm determines that fPaint is TRUE, invalidates the client rectangle and exits. As a result of invalidating the client rectangle, Windows® (1204) sends a WM_PAINT message to the access program (1206). On receipt of WM_PAINT, the access program (1204) checks the value of fPaint for each state machine, and if TRUE, sets fPaint to FALSE and redraws the visible subregion of the selectable region associated with that state machine and any menu option located thereon. The color of the redrawn visible subregion is determined by the value of the Color variable for that state machine. The incremented value of pPocket->Color results in a slight brightening of selectable region (2348) and reduces the difference between pPocket->Color and pPocket->CrestTide, corresponding to the dwell period required to select the associated selectable region. After redrawing, control returns to Windows® (1204).

Shortly before or shortly after the state machine associated with selectable region (2348) receives EV_CORRIDOR, all other state machines each receive EV_MOVEMENT and each makes the

state transitions from ST_EBB_TIDE to ST_DECAY to ST_EBB_TIDE.

This scenario is repeated at 54 millisecond intervals while the cursor hotspot travels along path (2322) to location (2326), a location intersecting corridor (2308). Between this location (2326) and location (2328), a location intersecting corridor (2306), along path (2322), the procedure CreateEvent determines that all state machines should receive EV_MOVEMENT, driving each of them from their current state to ST_DECAY and back to their current state. As described in the example in the detailed description of the Perimeter Menu aspect of the invention, ST_DECAY state processing darkens the selectable region associated with the state machine, but not below a predetermined brightness represented by the variable InitialColor. Thus selectable region (2348) darkens when the cursor hotspot no longer intersects corridor (2308). From location (2328) to location (2330), the procedure CreateEvent determines that the state machine associated with selectable region (2346) should received EV_CORRIDOR and all other state machines EV_MOVEMENT. Consequently, selectable region (2346) gradually brightens up to a ceiling represented by pPocket->InitialColor plus 80% of the difference between pPocket->CrestTide and pPocket->InitialColor. The duration of dwell time required for selection of selectable region (2346) is thus reduced to approximately 20% of the dwell period required without Facilitated Dwell.

Preferably, the Direction and Intersection subaspect of the invention is implemented by making the changes to the prototype described for the Facilitated Dwell subaspect, except that, in incrementing pPocket->Color in ST_CORRIDOR, the upper limit for pPocket->Color in ST_CORRIDOR state processing is pPocket->CrestTide minus pPocket->Increment. Assuming these changes, a selectable region whose associated Color variable is at this upper limit is selected during processing of the WM_TIMER message immediately following the intersection of the cursor hotspot and the selectable region.

Preferably, the Direction subaspect of the invention is implemented by making the changes to the prototype described for the Direction and Intersection subaspect of the invention, except that (1) the corridors are narrow, as illustrated in Figure 40; and (2) the pseudo-code for state processing in ST_CORRIDOR is as follows:

```
        case ST_CORRIDOR:
                          /* set state to previous state */
```

```
                        /* in preparation for the next */
                        /* state transition            */
set pPocket->State to pPocket->PreviousState
increment pPocket->Color by
pPocket->CorridorIncrement  but not above
pPocket->Ceiling
if pPocket->Color was changed
    set pPocket->fPaint to TRUE
set fInternalEvent to TRUE
if pPocket->Color was changed from a value
below
pPocket->CrestTide to a value greater than or
equal to
pPocket->CrestTide
    set Event to EV_STEP_UP
else
    set Event to EV_NULL
break
```

State ST_CORRIDOR may now generate the internal event EV_STEP_UP, as state ST_DWELL does in the detailed description of the Perimeter Menu aspect of the invention. A state machine in state ST_EBB_TIDE having a Color variable equal to or exceeding the CrestTide variable, will transition via PocketFsm[ST_EBB_TIDE][EV_STEP_UP] to ST_SELECTED, and perform the ST_SELECTED state processing described in the detailed description of the Perimeter Menu aspect of the invention.

Preferably, the Appraisal subaspect of the invention is implemented by making the changes to the prototype described for the Facilitated Dwell subaspect, except that (1) the corridors are visible on the display (2112), (2) one of the selectable regions is designated to be the target selectable region and this is indicated to the operator, (3) cursor locations are stored in memory (2106), and (4) following an intersection of the cursor hotspot and the target or selection of a selectable region other than the target, path directness is measured in accordance with the stored cursor locations.

The preferred embodiment of the Drift Attenuation aspect of the invention will now be described in

detail from an implementation perspective. Preferably, the Drift Attenuation aspect is implemented by modifications to the access program (1206) described in the detailed description of the Perimeter Menu aspect of the invention, modified as described above in the description of the implementation of the preferred embodiment of the Facilitated Dwell subaspect of the invention and further modified as follows: (1) add two booleans to the data set associated with each state machine, one called fDirectPath, the other fAttenuateDrift, and initialize each of them in all state machines to FALSE; (2) in both ST_DECAY and ST_CORRIDOR, set both pPocket->fDirectPath and pPocket->fAttenuateDrift to FALSE; (3) append to ST_ENTRY state processing corresponding to the following pseudo-code:

```
if pPocket->Color equals or exceeds
(pPocket->InitialColor + (0.5 * (pPocket->CrestTide -
pPocket->InitialColor)))
    set pPocket->fDirectPath to TRUE
```

(4) append to ST_DWELL state processing corresponding to the following pseudo-code:

```
if the present cursor position intersects the edge of
the Windows® cursor clipping rectangle and
pPocket->fDirectPath is TRUE
    set pPocket->fAttentuateDrift to TRUE
if pPocket->fAttentuateDrift is TRUE
    store the difference in each of the x and y
    coordinates ("delta") between consecutive cursor
    locations in a circular buffer accommodating the
    last ten deltas, overwriting the oldest delta with
    the newest delta
    if ten deltas have been accumulated
        calculate the average acceleration indicated
        by the last ten deltas
        if the average acceleration is negative
            set the cursor at the location one half
            the distance between the current cursor
            location and the previous cursor location
```

display the cursor at this new cursor location

E. Intersection

The preferred embodiment of the Intersection aspect of the invention will now be described in detail from a functional perspective using an example depicted in Figures 44, 45, 46. Figure 44 shows the display (2112) of a general purpose computer system (2218 in Figure 15) to which is coupled a pointer (2202). Eight regions are delimited with respect to the display (2112) and together circumscribe region (2650) on the display (2112). Four of these regions, (2602), (2612), (2622), and (2632), are entirely on the display (2112). Each of the other four regions respectively includes both a visible subregion ((2606), (2616), (2626), and (2636)) on the display (2112) and an invisible subregion ((2604), (2614), (2624), and (2634)) adjacent and outside the display (2112). Assume, for example, that the pointer is indicating location (2656) on the display (2112) and that the operator moves the pointer so that the location indicated by the pointer first intersects one of the regions at location (2652) in region (2612). Upon this intersection, the display changes to that shown in Figure 45. Figure 45 depicts a selectable region consisting of the union of invisible subregion (2714) and visible subregion (2716), hereinafter referred to as selectable region (2714/2716). Selectable region (2714/2712) is associated with menu option "sumac". In the preferred embodiment, the operator may select menu option "sumac" by dwelling on any part of the selectable region for the selection threshold period. Assuming, for example, that instead of moving the pointer from a position indicating location (2656) to location (2652), the operator instead moves the pointer so that the location indicated by the pointer first enters one of the regions at location (2654) in region (2614/2616). Upon this intersection, the display changes to that shown in Figure 46. Figure 46 depicts a selectable region consisting of the union of invisible subregion (2814) and visible subregion (2816), hereinafter referred to as selectable region (2814/2816). Selectable region (2814/2816) is associated with menu option "vort<space>x". In the preferred embodiment, the operator may select menu option "vort<space>x" by dwelling on any part of the selectable region for the selection threshold period.

In the preferred embodiment, each of the other seven regions shown in Figure 44 is associated with a selectable region and each selectable region is associated with a menu option. The menu options shown in Figure 44, in addition to "sumac" and "vort<space>x" are "wizen", "backspace", "words", "talk", ldhbfk" and "ypgqj,". The operator may select the menu option associated with any one of

the selectable regions by moving the location indicated by the pointer from circumscribed region (2650) into the region associated with the selectable region and then dwelling on the selectable region for the selection threshold period. Each selectable region preferably includes all the area of its associated region.

An operator having impaired ability to maintain a body member in a steady position but who can control the point at which the location indicated by a body member enters a region may, in accord with the Intersection aspect of the invention, use his relatively unimpaired motor capability to selectively enlarge a selectable region or determine which of two or more selectable regions will occupy a predetermined area, thus making it easier for him to select. If the general purpose computer system of the preferred embodiment is coupled to a speech synthesizer and the menu options are letters or words, an operator with impaired speech may select or spell words and speak them.

Figures 47 and 48 illustrate the upper right corner of a display in accordance with an alternative embodiment of the Intersection aspect of the invention. Figure 47 depicts the upper right corner of a display (2112) of a computer system (2116) having thereon two regions, (1404) and (1402), each associated respectively with a selectable region, each selectable region associated respectively with menu options "bdfhkl" and "<space>cmnrst". The selectable region associated with region (1402) includes all of region (1402). The selectable region associated with region (1404) includes all of region (1404) plus area (1406) between region (1404) and the right edge of the display (2112). Assuming the operator uses a pointer to indicate a location on the display and that the location to first intersect the union of regions (1402) and (1404) intersects region (1402), the display remains as shown in Figure 47. Dwelling in area (1406) operates to select the menu option "<space>cmnrst". If instead the location to first intersect the union of regions (1402) and (1404) intersects region (1404), the display changes to that shown in Figure 48. Dwelling in area (1406) then operates to select the menu option "bdfhkl".

The preferred embodiment of the Intersection aspect will now be described in detail from an implementation perspective. The Intersection aspect is preferably implemented by modifications to the access program (1206) described above in the detailed description of the Perimeter Menu aspect of the invention. The modifications are: (1) add a row to the state table aPocketFsm at row index 18 for a new state, ST_EXIT and initialize the value of aPocketFsm[ST_EXIT][EV_NULL] to 4, the value of ST_LOW_TIDE; (2) at initialization time, change

aPocketFsm[ST_LOW_TIDE][EV_CROSS_OUT] to 18, the value of ST_EXIT; (3) at initialization time for each state machine, (a) if the visible subregion associated with the state machine does not abut the edge of the display, set fInterior to TRUE, otherwise set fInterior to FALSE; (b) initialize iAdjacentPocket to the index of the state machine associated with the adjacent region. For example, assuming the index of the state machine associated with region (2614/2616) in Figure 44 is 2 and the index of the state machine associated with region (2612) in Figure 44 is 3, iAdjacentPocket in the data set associated with the state machine associated with region (2614/2616) is initialized to 3 and iAdjacentPocket in the data set associated with the state machine associated with region (2612) is initialized to 2; (c) initialize the second array of points to define the boundaries of the region associated with the selectable region associated with each state machine, for example, region (2612), and initialize the first array of points to define the boundaries of the visible subregion of the selectable region associated with the state machine, for example, visible subregion (2712); (4) remove creation of Windows® regions corresponding to visible subregions from the access program (1206) initialization; (5) append to ST_ENTRY state processing corresponding to the following pseudo-code:

```
if pPocket->fInterior equals TRUE
    if pPocket->hRegion is not NULL
        delete the Windows® region having the handle
        pPocket->hRegion
    create a Windows® region having the boundaries
    defined by the second array of points associated
    with this state machine and set pPocket->hRegion
    to the handle to this region
    set pPocket->fPaint to TRUE
send EV_RESET to all state machines except this one
and the state machine having the index
pPocket->iAdjacentPocket
set pAdjacentPocket to point to the data set
associated with the state machine having the index
pPocket->iAdjacentPocket
delete the Windows® region having the handle
pAdjacentPocket->hRegion
set pAdjacentPocket->hRegion to NULL
```

```
set pAdjacentPocket->fPaint to TRUE
```

(4) append to ST_RESET state processing corresponding to the following pseudo-code:

```
if pPocket->hRegion is not NULL
    delete the Windows® region having the handle
    pPocket->hRegion
create a Windows® region having the boundaries defined
by the second array of points associated with this
state machine and set pPocket->hRegion to the handle
to this region
```

An example of the selection of selectable region in accord with the Intersection aspect of the invention will now be described with reference to Figures 44 and 45. Following initialization, assume that the operator moves the pointer (2202) from a position indicating location (2656) toward location (2652) in Figure 44. At the next expiration of the cursor polling timer, the procedure CreateEvent sends an EV_MOVEMENT event to the state machine associated with the selectable region associated with the menu option "sumac". The event EV_MOVEMENT drives this state machine from its current state, ST_RESET, to ST_EBB_TIDE. The pseudo-code for ST_EBB_TIDE in procedure PocketFsm is a break statement, indicating that no state specific action is taken at this time, other than the transition to ST_EBB_TIDE. Control returns to Windows® (1204). At the expiration of the cursor polling timer after the location indicated by the pointer reaches location (2652), the procedure CreateEvent sends event EV_DWELL to the state machine associated with the selectable region associated with the menu option "sumac". EV_DWELL drives this state machine from ST_EBB_TIDE to ST_ENTRY. Following the pseudo-code for ST_ENTRY state processing shown above and in the Procedure PocketFsm, fInternalEvent is set to TRUE, Event is set to EV_NULL, the Windows® region corresponding to region (2612), ie. the Windows® region having the handle pPocket->hRegion, is deleted and a new Windows® region having the boundaries indicated in the first array of points, ie. visible subregion (2712) in Figure 45, is created and the handle stored in pPocket->hRegion. pPocket->fPaint is set to TRUE, EV_RESET is sent to state machines associated with regions other than (2612) and (2614/2616). Data in the data set associated with the adjacent region (2614/2616) is now modified. The Windows® region corresponding to region (2614/2616) is deleted, hRegion for the state machine associated with that region is set to NULL and fPaint associated with that state machine is

set to TRUE. The event EV_NULL drives the state machine associated with selectable region (2714/2712) to ST_LOW_TIDE. The pseudo-code for ST_LOW_TIDE is only a break statement, so there is no state specific action for ST_LOW_TIDE other than entry into this state. pPocket-fPaint is TRUE so the client rectangle is invalidated, resulting in the redrawing of Windows® regions associated with state machines having fPaint equal to TRUE so that the display (2112) appears as shown in Figure 45. Control returns to Windows® (1204).

Dwelling at any location within selectable region (2714/2712) now causes the procedure CreateEvent to send EV_DWELL to the state machine associated with this selectable region. Selection of this selectable region proceeds as described above in the detailed description of the Perimeter Menu aspect of the invention.

Assuming the operator moves the location indicated by the pointer out of selectable region (2714/2712) prior to selection. the procedure CreateEvent sends the event EV_CROSS_OUT to the state machine associate with that selectable region, driving it to ST_EXIT. The state processing for ST_EXIT causes the display (2112) to change to that shown in Figure 44.

F. Alignment

The embodiment of the Alignment aspect of the invention as implemented in the prototype will now be described in detail from a functional and implementation perspective using an example depicted in Figures 49, 50, and 51 . Each of these Figures depicts the upper right corner of a display (2112) having two visible subregions on the display. In these Figures. no subregions outside the display (2112) are shown. Alignment is achieved in several steps and requires operator interaction with the apparatus. For purposes of this example, assume that Figure 49 depicts the upper right corner of the display (2112), that an operator, fitted with a head pointer, desires to keep the cursor on the display directly in his line of sight and that the location indicated by the pointer is presently 15 degrees to the right of the location of the arrow cursor (1802). The operator now dwells on selectable region (1834) for an predetermined period ("the lock threshold") which preferably is significantly greater than the selection threshold period. The apparatus responds to this extended dwell period by changing the display to that shown in Figure 49. The arrow cursor is removed from the display and the lock icon (1902) is displayed in a predetermined location of the intersected selectable region ("lockspot") on the display. The lock icon remains on the lockspot for a predetermined period ("the lock period"); it does not move responsive to the operator's head

movement. While the lock icon is displayed, the operator turns his head, bringing his line of sight into alignment with the lockspot. At the expiration of the lock period, the apparatus changes the display to that shown in Figure 51. The lock icon is erased and the arrow cursor appears in the lockspot, which is where the operator is now looking. The arrow cursor moves in response to the operator's head movement.

An operator who loses alignment between location indicated by his pointer and the cursor may thus initiate an alignment sequence, and then, by moving his head or other body member when the prototype indicates he should do so by displaying the lock icon, regain alignment. That the lock icon is displayed indicates to the operator that he can align his head or other body member. The position of the lock icon indicates to the operator the location on the display with which he should align his head or other body member. This is the location where the arrow cursor will appear at the expiration of the lock period.

The Alignment aspect will now be described in detail from an implementation perspective as implemented in the prototype. The Alignment aspect of the invention is implemented an integral part of the state machine described in the detailed description of the Perimeter Menu aspect of the invention, using the same state machines and initialization, with the exception that aPocketFsm[ST_CREST_TIDE][EV_CEILING] is changed from 9, the value of ST_DWELL, to 14, the value of ST_BEGIN_LOCK. The operator initiates the alignment process by moving the cursor so that the cursor hotspot intersects a selectable region. As an example, Figure 49 shows the arrow cursor (1802) intersecting selectable region (1834). The operator then dwells on the selectable region for the lock threshold, preferably at least one second greater than the selection threshold period. This operator action causes the state machine associated with the intersected selectable region to reach state ST_CREST_TIDE. On receipt of the first WM_TIMER message following entry into state ST_CREST_TIDE, the procedure CreateEvent creates event EV_CEILING, which drives the state machine from state ST_CREST_TIDE to state ST_BEGIN_LOCK. The state processing within state ST_BEGIN_LOCK beeps, sets the system cursor location to the selectable region's lockspot, sets the system cursor to null erasing the arrow cursor, displays a the lock icon (1902 in Figure 50) on the selectable region's lockspot and initializes the global variable iLockCursor to the number of expirations of the cursor polling timer corresponding to the period of time the cursor will be locked (the "lock period") configured by the operator, preferably two seconds, and control is returned to Windows® (1204). Following the next expiration of the cursor polling timer, the procedure CreateEvent may generate an event

EV_DECAY, EV_DWELL, EV_CROSS_OUT, EV_MOVEMENT or EV_CEILING. Each of these events drives the state machine from state ST_BEGIN_LOCK to state ST_LOCK. Within state ST_LOCK the system cursor is moved to the selectable region's lockspot and iLockCursor is decremented. Then it is determined whether iLockCursor equals zero. If not, control returns to Windows® (1204) for another iteration through ST_LOCK. During the lock period, the system cursor is moved to the lockspot upon every expiration of the cursor polling timer, thus inhibiting movement of the cursor from the lockspot so that, during the lock period, the operator may move the location indicated by the pointer while the lock icon remains on or very close to the selectable region's lockspot. When, eventually, iLockCursor is decremented to zero, the global Event is set to EV_NULL and fInternalEvent is set to TRUE so that another state transition occurs immediately. This transition drives the state machine from state ST_LOCK to state ST_END_LOCK. Within state ST_END_LOCK, the lock icon is erased, Windows® (1204) is directed to display the arrow cursor (2002) at the lockspot, as shown in Figure 51, the fPaint flag associated with the intersected selectable region is set to TRUE so that the selectable region will be drawn, restoring the background behind the erased lock icon. Assuming the cursor hotspot remains on the selectable region for another 54 milliseconds, CreateEvent generates EV_DWELL, which drives the state machine to ST_DISCARD. Referring to the pseudo-code in PocketFsm, ST_DISCARD state processing sets State to PreviousState, returning the state machine to ST_END_LOCK and in effect, discarding the last event. Following the expiration of the cursor polling timer after the operator moves the cursor out of the selectable region it presently intersects, the procedure CreateEvent generates an event EV_CROSS_OUT which drives the state machine from state ST_END_LOCK to state ST_SELECT_AND_OUT. The access program (1206) performs the state processing for state ST_SELECT_AND_OUT and subsequent states as previously described in the description of the Perimeter Menu aspect of the invention.

In the prototype, the operator may initiate alignment by depressing any character key on the keyboard. On receipt of a WM_CHAR message from Windows® (1204), the access program (1206) removes the arrow cursor from the display and displays the lock icon at a predetermined location on the display. In the prototype, the predetermined location is the center of the display (2112). After a predetermined period, two seconds in the prototype, the lock cursor icon is erased and the arrow cursor displayed at the predetermined location.

In the prototype, the cursor is automatically centered if the cursor hotspot does not move for two minutes. Lack of movement of the cursor hotspot is detected in the procedure CreateEvent, which

generates the event EV_IDLE_TIMEOUT for all state machines. The state processing of each state machine on receipt of EV_IDLE_TIMEOUT depends upon its current state. State machines in states ST_INITIAL and ST_RESET stay in those states. State machines in all other states in which an external event can be received are driven to ST_IDLE. Referring to the pseudo-code in PocketFsm, ST_IDLE state processing moves the cursor to the center of the display, sets fInternalEvent to TRUE and sets Event to EV_NULL. PocketFsm[ST_IDLE][NULL] equals 3, the value of ST_RESET. The access program (1206) performs the state processing for the ST_RESET and subsequent states as described in the description of the Perimeter aspect of the invention.

G. Length Order

The preferred embodiment of the Length Order aspect of the invention will now be described in detail from a functional and implementation perspective using an example depicted in Figure 52 and described in the detailed description of the Location Indication aspect of the invention. Assume, for purposes of this example, that the operator has previously selected the letter "s". In the preferred embodiment, the string "s" is passed from the access program (1206 in Figure 16) via the Windows® Dynamic Data Exchange ("DDE") interface to a database program (1210 in Figure 16), preferably the FoxPro for Windows® version 2.6 program, available from Microsoft Corporation, Redmond, Washington, USA. The FoxPro program looks up the record having the index "s" in a database composed of 26 letters, one for each letter of the alphabet. Each record includes one field for a letter of the alphabet and 12 fields containing the 12 most frequently used English words beginning with that letter. The 12 words in the record are ordered primarily by length, determined by the number of letters in each word, and secondarily by alphabetic order. The FoxPro program returns these 12 words to the access program (1206) and these are displayed on the display (2112) as named menu options. The twelve named menu options, ordered as described and depicted in Figure 52, are "so", "say", "she", "said", "show", "some", "such", "state", "school", "social", "service", and "student". Preferably, only the root form of inflected forms of words which can be created through available suffixes ("root word") may be displayed as named menu options, so that the limited number of available menu options in combination with the apparatus' capability to add suffixes offers a large number of inflected forms.

Words which may be named menu options in the same menu may be ordered by any suitable method. Preferably ordering is done by an ordering program operating on a corpus of text or speech including text or speech produced by individuals whose age, sex, geographic location and

disability are the same as or similar to that of the operator. The ordering program determines the frequency of use of root words in the corpus, selects the twelve most common root words, beginning with every possible combination of one, two and three letters, and stores them in three FoxPro databases for one, two and three letter word beginnings respectively, the words in each record ordered as described above. Ordering the words prior to a request minimizes the delay between the operator's selection of a letter or letters and the display of the named menu options. Preferably, the ordering program also creates a database of records for root words beginning with four or more letters. Each record includes the words and its frequency of use in the corpus. When the operator selects four or more letters consecutively, the access program (1206) requests via DDE that the FoxPro program (1210) look up words starting with four or more letters in the database for words beginning with four or more letters, select the 12 most frequently used words matching the selected letters, order them as described above, and return them to the access program (1206).

An operator searching named menu options for a desired menu option may start his search in the area on the display most likely to contain the desired menu option. Upon comparison of the length of the desired menu option to a displayed menu option, the operator may determine whether to continue his search from the displayed menu option toward the front of the list or toward the rear of the list, or to jump to another displayed menu option in the list Further, he may make this determination more quickly than if the displayed menu options were sorted conventionally. The reduced menu option search time increases the operator's productivity with respect to conventional menu interfaces.

H. Location Indication

The preferred embodiment of the Location Indication aspect of the invention will now be described in detail from a functional perspective using an example depicted in Figure 52. Figure 52 shows the display (2112) of a general purpose computer system (2218 in Figure 15) having thereon eight selectable regions, each associated respectively with a menu option. Each of the eight selectable regions consists of the union of a visible subregion on the display (2112) and an invisible subregion (not shown) located outside the display (2112) and adjacent the visible subregion. Selectable region (4301) is associated with menu option "so", selectable region (4303) with menu option "say", selectable region (4305) with menu option "she", selectable region (4307) with menu option "suffixes", selectable region (4309) with menu option "words", selectable region (4311) with menu option "some", selectable region (4313) with menu option "show" and selectable region (4315)

with menu option "said". Also shown on the display (2112) are 12 indicating regions, each associated respectively with a menu option. Indicating region (4351) is associated with menu option "so", indicating region (4353) with menu option "say", indicating region (4355) with menu option "she", indicating region (4361) with menu option "some", indicating region (4363) with menu option "show", indicating region (4365) with menu option "said", indicating region (4371) is associated with menu option "such", indicating region (4373) with menu option "state", indicating region (4375) with menu option "school", indicating region (4381) with menu option "student", indicating region (4383) with menu option "service" and indicating region (4385) with menu option "social". Each indicating region is located on the display (2112) in the region (4350) circumscribed by the selectable regions. In accord with the Location Indication aspect of the invention, the location of each of the indicating regions (4351), (4352), (4355), (4361), (4363) and (4365) indicates the location of each of the selectable regions associated with the menu option associated with the indicating region. These selectable regions, respectively, are (4301), (4303), (4305), (4311), (4313) and (4315).

In the preferred embodiment, selection of menu option "words" causes selectable region (4301) to be associated with menu option "such" instead of menu option "so", selectable region (4303) to be associated with menu option "state" instead of menu option "say", selectable region (4305) to be associated with menu option "school" instead of menu option "she", selectable region (4311) to be associated with menu option "student" instead of menu option "some", selectable region (4313) to be associated with menu option "service" instead of menu option "show", and selectable region (4315) to be associated with menu option "social" instead of menu option "said". In the preferred embodiment, following the selection of menu option "words", the menu option newly associated with each selectable region is displayed on that selectable region (not shown). Following the selection of menu option "words", indicating regions (4371), (4373), (4375), (4381), (4383) and (4385) each indicate the location of each of the selectable regions associated with the menu option associated with the indicating region.

The indicating regions and the menu options displayed thereon in Figure 52 are disproportionately large relative to the rest of Figure 52. They are approximately 1.5 times their proportionate size. They are represented as shown in Figure 52 in compliance with Patent Cooperation Treaty Rules requiring a minimum size for letters in figures.

In the preferred embodiment of the Perimeter Menu aspect of the invention, all the menu options